TOWARDS A POST-INDUSTRIAL ARCHITECTURE:
Design and Construction of Houses for the Information Age

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Submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of Master of Science in Architecture Studies at the Massachusetts Institute of Technology

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Originally from Colorado, Greg attended the University of Oregon, where he received his Bachelors of Architecture in 1997. While in the Pacific Northwest, encounters with industrial mill structures proved to be both exhilarating and illuminating, and planted the seed for an inquiry into industrial architecture. This work represents but one format for exploring the ramifications of industrial processes and aesthetics in the realm of architecture, and is understood to be part of a larger lifelong exploration into composition, montage, complexity, and the pursuit for individual freedom.

I wish to extend all my gratitude and dire appreciation to Sheri Demchak, for her willingness to stay the course and endure with me these last two years. Also, for Gentry and Serene Demchak, for whose intimate and authentic bond I am forever grateful. And for my parents, Leonard and Jill Demchak, to whom I owe everything.
ABSTRACT:

Towards a Post-Industrial Architecture: Design and Construction of Houses for the Information Age

Gregory L. Demchak

Submitted to the Department of Architecture on May 18, 2000 in partial fulfillment of the requirements for the degree of Master of Science in Architecture Studies at the Massachusetts Institute of Technology

The design and construction of modern residential architecture, which came into critical focus by architects of the Machine Age, continues to be a priority in the architectural discourse. For Modern architects, the desire to relate the house to industrial processes was an aesthetic and social imperative that never gained popular acceptance. Today, mention of an industrial, factory-produced house conjures images of mobile homes and cheap construction rather than innovative modern design. At the same time, the typical suburban single-family unit offers little in the way of innovation or individual expression. Land developers, rather than architects or planners, have taken control of the residential market, and do not offer architectural design services to average consumers. As a result, the design of homes adheres to generic standards that are neither flexible nor adaptable to changing family and individual needs. Stylistic choices are extremely limited. The topic of this thesis is to address these and other issues currently impeding the development of innovative residential architecture by exploring the use of computational tools to generate unique architectural solutions. Strategies for obtaining meaningful information from clients that generate spatial rules are explored, as well as a construction methodology that supports multivalent, adjustable architecture.

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INTRODUCTION:

The industrialization of Western culture, which began more than two hundred years ago with the introduction of the steam engine and continues to this day, brought the machine and all of its constituent products into virtually all aspects of modern existence. From the way we live and work, to how we recreate and communicate, the presence of the machine has dramatically changed the social and technological organization of culture. The very fabric of social order has become increasingly dynamic as innovations in communication, transportation, habitation, consumption, entertainment, and production continue to unfold. With the era of the computer well under way, the world is fast becoming an interconnected global marketplace that never sleeps. Advancements in networked data highways have brought all corners of the world market into a single, distributed, and vastly diversified field of shared knowledge. In turn, the consumer market is witnessing a shift from an industrial model of production to a post-industrial model; where information and knowledge, rather than labor and geographic resources, have become primary commodities. Virtually every object we interact with is a product of industrialization, and in the near future, every object will be part of an ever-expanding network of information.

This manufactured reality that surrounds and defines the context in which we operate is simultaneously fascinating and disturbing. We live in a world of vast webs of interconnected systems: unintelligible distribution systems deliver all manner of mass-pro-

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1 The Internet has expanded the availability of information in ways never before possible. The potential for cross-cultural pollination, the location of affinity groups, meeting random individuals, or finding highly select data are all available to a world wide user group.

2 In Daniel Bell's new forward to The Coming of Post Industrial Society, He states, "Post-industrial society makes higher education—human capital—the foundation for position and privilege in the society." Page lxv.

3 MIT Media Lab is working with Procter and Gamble to create digital radio frequency tags that will replace the UPC (Universal Product Code) barcode standard, and thus distribute information everywhere. All manufactured objects will be stamped with highly specific information about that particular product. In other words, every object will have unique data associated with it.
duced objects anywhere on the planet; communications move through invisible fields of data; sound waves, microwaves, and radio waves are everywhere yet nowhere. We are unimaginably connected, and yet somehow disconnected. Objects connect us, transport us, and define us, yet we rarely have any notion about how an object is made, where it came from, who (or what) designed it, and why it exists at all. It has become difficult to imagine being in the world without the technological and economic structures that support our existence. Nonetheless, one tries, however desperately, to express identity within this hyper-complex social milieu; to have a sense of place in an otherwise placeless void; to locate and define individual qualities and characteristics in the realm of the mass-produced. We seek out products that will provide both a sense of distinction and belonging: something that is both specific and yet strangely global. Like everyone else, we want a car; yet also want it to be somehow distinctively suited to our specific needs and desires. The modern cellular phone connects us to others, yet disconnects us from the mechanism itself—we have no sense about how or why it operates, only that it allows us to communicate whenever and wherever we so desire. As technology continues to physically connect to our being, it will necessarily become more personal and individually tailored. Machines will become expressions of individual identity.

The need to assert identity is fundamental to human existence, and influences how we shape our public and private environments. How we assert identity involves all aspects of our life: where we live, who we live with, what products we buy, what type of work we do, what we eat, how we have fun. Identity is intimately woven into our homes and the community to which we belong. It is from this vantage point, that of looking toward modes of self-expression, that the dwelling will be explored in relation to emerging technological opportunities. The current standards of house construction currently fall short of satisfying a diversified social environment and do not encourage the expression of identity or community. A growing sense that something has gone wrong is working its way into public consciousness, as the effects of sprawl continue to eradicate the countrysides. Expanding edge cities, following a development pattern that
is no longer in sync with culture, technology or environment, continue to decimate land and social fabric. As New Urbanists are quick to note, "Out of this evolution of the modern metropolis there has grown a profound sense of placelessness. A homogenous quality overlays the unique nature of each place with chain-store architecture, scaleless office parks and monotonous subdivisions." A demand for better communities and houses will grow, creating a demand for new tools and systems of building that grapple with the complexities of life the twenty-first century. An incredible opportunity presents itself: to design and implement a computationally driven architectural framework that can facilitate a wide range of complex needs and desires. In other words, computer assisted design tools, if crafted properly, can revolutionize the way homes, and by extension, communities, are designed, built, and ultimately lived in.

Where and in what we live largely determines how we live. In this sense, the basic dwelling unit, whether we are referring to a single family detached house in the suburbs, or a studio loft in a high-density urban landscape, represents a relationship between the homeowner and cultural innovations in art, technology, life-style, and the consumer market. More often than not, our relationship with consumer products, the house included, is ambiguous at best. The dislocation of consumers from producers is creating a myopic sensation of disjunction that is not only confusing, but architecturally defunct. As recourse, people look toward "customization" as a way of personalizing objects and space: an attempt to localize and make specific inherently nonspecific objects. These customizations are often cosmetic changes, superficialities that provide a new or distinctive look, but rarely suggest new types of use or adaptation. While interesting, cosmetic, antiseptic choices are not the focus of this discourse. Instead, I am interested in exploring how the design of dwelling environments can be augmented such that the complexity of post-industrial culture becomes manifest and expressed. Thus, I ask: can we extend the concept of the house beyond the cosmetic?

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4 See Joel Garreau: Edge Cities: Life on the New Frontier (1991)
Can we achieve more adaptable-flexible architecture? Can computation tools be developed that radically change the way consumers approach the design and construction of new houses and communities? If so, then the process needed to achieve this end needs to take into consideration the large diversity of potential users, building materials, and economic strata. The process will have to be dynamic, having the ability to adjust and expand as markets and economies do. Most importantly, it will have to forge a new relationship between consumers and industry. Thus, the vision is to create a viable alternative to current housing trends, which is economically competitive, technologically superior, and offers clients more control in the design of their living environments. Post-industrial dwellings must be economical, mutable, multifunctional, reversible, detachable, compressible, extendable, and adjustable.

In providing more opportunities to have a decision-making role in the generation of home designs, individuals will gain more control over the organization and appearance of their home. This is important in two aspects: (1) homes will become more expressive of identity, and (2) it strips away the overbearing control that developers have on how homes "should" look. The essential component to this ideology is a mechanism that connects consumers directly to the building product market. Connecting the consumer directly with industry and construction products can open the door to an endless possibility of solutions. One can imagine neighborhoods, not unlike some built in the United States in the early 1920's, where every home is distinctive, uniquely detailed, and formally eccentric. One also imagines the homes to be highly adaptable to changing user needs over varying amounts of time, be it daily events, seasonal fluctuations, or long term life cycles. These new homes will not only be unique in appearance, but in spatial and functional organization as well. Homes would integrate user-specified montages of various materials, objects, and volumes via a robust computational grammar based on an adaptable construction system. These dwellings, outfitted with nonpermanent dividers and storage systems, would encourage various scales of change, which would in turn be responsive to fluctuating trends in habitation. Thus, homes would be initially suited to one particular family profile, but have the ability to be adjusted easily to meet the needs of a very different family.

Levittown, NY. Typical house facade. This house, with 700 square feet and a detached one-car garage, became the dominant housing type after 1945.
This proposal outlines a computational system that organizes preferences, aesthetics, and spatial relationships into an architecture that responds directly to specific contextual, individual and ideological conditions. Concise data collection tools and a new construction methodology will facilitate an open architecture that is free to transform and accommodate the needs and desires of individual homeowners. By 'open' architecture, I am referring to a condition in which the individuals who inhabit such architecture are free to openly define and parameterize the space they use. An open architecture makes few assumptions about how individuals should live, while supporting as many different lifestyles as possible by allowing transformation and reinterpretation to occur.

Both strategic and tactical structures support the system; with strategic structures offering methods for garnering information and processing it, and tactical structures generating innovative construction technology. Together, the collection of data combined with a flexible architectonic system can create dwellings that are individually tailored, yet able to adjust to any number of other usage patterns. I will go so far as to say that many homes generated using the tool will not be used in the traditional sense of the word "home", but as places of business, live-work communities, or even temporary shelters for nomadic citizens. Use patterns would not be restricted, but allowed to expand into all modes of human existence. Zoning regulations and aesthetic restraints would be lifted, creating mixed use buildings and organic synergetic growth to begin. If homes can support this type of richness and diversity of individuals, then the very fabric of urban and suburban will undergo radical reconstructions, becoming, as Lebbeus Woods would assert, "heterarchical."

By family, I am not referring to any "typical" definition, for there is no such thing anymore. A family may consist of any group of individuals who co-habit a dwelling. Thus, in this research I consider five college students living in an apartment a "family" as much as a married couple with nine kids.
Proposed is a tactical perspective, based on a new construction methodology for the development of future houses. The proposed system calls for an integrated component-based architecture that is capable of supporting a wide range of activities. It will be a pre-fabricated system that draws on some previously attempted methods of producing industrial dwellings, but takes advantage of the computer and the ability to make customized decisions using a networked computer interface. The system makes use of grammatical spatial languages to create complex geometric shapes; it is not a mechanism for creating "minimal standards of living". The system looks the other direction, asserting maximum standards of use, where functional zones are no longer compartmentalized into predetermined units of space, but left to be arranged and rearranged at the discretion of inhabitants. Thick-core service areas, and structure remain as intact skeletal frameworks, around which, and along which, living space grows. The ability to adjust variables and explore trade-offs is a fundamental criterion for such a device, and explored throughout the thesis.

Over the course of the last century, there have been numerous attempts to bring the standards of home design and construction up to the standards present in other markets. Systematic, factory-produced dwellings have been explored and built, but they have not made significant headway in the housing market. The consistent failure of 'technologically advanced' homes may come as a surprise. However, the more one studies industrial housing, the more one sees the same problems and issues filter to the foreground in a predictably devastating fashion. Construction methods have been slow to

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7 Woods. *Anarchitecture: Architecture as a Political Act.* age 14-19 Woods promotes the concept of 'freespace architecture', in which form and function become entirely severed in favor of free expression and assemblage within a constantly shifting cultural praxis: "I asserted that the freespace structures and the constantly shifting pattern and network they created were 'heterarchical', and therefore an integral part of a global structure of freely determined communication and authority befitting a highly mobile and culturally dynamic contemporary urban society."
change. While we have seen countless technologies proliferate our interior space, it is rare to find a building system that measures up to the sophistication of our DVD player, vacuum-packed dinners, or the complexity of a home computer. In most cases, solutions were naive, had limited criteria for aesthetic quality, lacked adaptability, and were ultimately more expensive to produce.

Industrialization of construction techniques have attempted, at least conceptually, to deliver systems that would provide individuals with more freedom to craft their own environments, to make innovation affordable, and to streamline production for efficiency. A belief that prefabrication would revolutionize the housing market has yet to occur beyond minimum standard housing, as was the case immediately after World War II for displaced war workers and veterans. The immense, fragmented housing market typically stymies these goals. The development of the single-family house has only moderately participated in the evolution of industrial production. Where it has participated, it is often in the realm of manufactured (mobile) housing, that leaves little to the imagination, and that has not expanded beyond the minimal HUD standards. Likewise, the current model of single-family development, seen spreading rampantly across the suburbs of the United States, has no clear method for addressing the dynamics of social and economic change. Homes built by developers adhere to generic standards that fail to respond to individual tastes, new technologies, or complex demographics. The trends toward job mobility, smaller family size, mixed living scenarios, and working from home have little if any influence in the vastness of suburban sprawl.

Sprawl has become the defacto example of a process known as “value engineering”, in which unnecessary details are stripped away one by one until the project hits its

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6 Department of Housing and Urban Development exists to help middle and low income families into government subsidized housing. They also set guidelines for mobile home construction and multi-family housing complexes.
targeted budget. As a result, communities must to contend with an artificial landscape engineered for the "market": a nebulous mixture of indistinguishable facades and curvilinear strips of asphalt. The pattern and effect is the same whether you happen to be in Memphis or Phoenix. In the suburbs, we encounter a commercially driven set of standards that have nothing to do with the local climate, culture, or sensibilities. The expression of identity is discouraged, and in many cases banned. Consequently, individuals have little recourse for creative living, and end up inhabiting totally neutralized homes. All the characteristics that are coming to define the information age are ostensibly left out: multi-disciplinary, interconnected, diversified, high-tech, adaptable, revolutionary.

A new model needs to be developed that can compete with, and eventually curb the expansion of these baseless homogeneous communities. Industrial processes, which have been slow to influence house construction, need to be re-examined. Prefabricated components complete with integrated services and wiring, can have any number of external treatments, thus enabling consumers to explore varied options before making a purchase. Industry has a critical role to play as well: use of composite materials, structural insulated panels, sustainable products, and recycled material should all be developed and offered as alternatives.

For an industrial process to succeed, it must provide a more superior system. That is, it needs to be more than just a technologically sophisticated high-end product, but a comprehensive way of building a house. It must be structurally sound, flexible, adjustable over time, and easy to assemble. In a similar vein, we should not conceive solutions as class icons or as permanent or historically bound reminders of a time and place long gone. They should be, on the other hand, free and open to critical reconstruction/deconstruction. In other words, the tendency to re-appropriate objects of mass-production should not be discouraged, but facilitated before a design is even finalized. The system will need to be robust enough for objects to be reassigned value and intended usage, and thus provide consumers with more leeway to "break the rules". (Of course, even a break from the rules will entail a logical rule for such activity in sphere of the program architecture.)

Lustron Houses. Prefabricated panels being ushered to doom. Can industrial houses ever survive in the market? If so, then how?
This new methodology will engage information connectivity and computation in an attempt to extend industrial production to end-users. The interaction will include the construction of a profile based on specific parameters, the generation of abstract spatial models, and the direct manipulation of components in a virtual-constructive world. Interface for design and conceptualization will ultimately be accessible via the World Wide Web, becoming a portal into a new generation of housing alternatives. That the tool will exist on the Internet lends itself to unpredictable exposure and usage, creating opportunities for anonymous individuals to experiment and produce virtual as well as physical architectures.

The industrial model of providing mass-produced disconnected stock material for the construction industry is no longer a responsible means of engaging production techniques and emerging design methodologies. It is failing to respond to developments in computational technology, which has expanded into practically every aspect of contemporary life. The constantly evolving information age that defines Post-Industrial culture is not only blurring, but also questioning the very boundaries of technology, communication and representation, creating complexities never before imagined. In an effort to create viable solutions for existing in such a context, new tools and design systems need to be explored that exploit and respond to this complexity. The home of the future will be responsive to changing technological advancements and ultimately become a vehicle for discovering new ways of living, thinking, and building.

The advent of ubiquitous computing has ushered in new modes of approaching design, production, and distribution. The relationship between a client and a service provider is no longer dependent on physical proximity, but the ability to connect to a network. The products that surround us are from all corners of the globe, and will continue to be so. The distribution of information and goods spreads across conglomerated economic structures and invisible telecom infrastructures, connecting consumers to a global web of interaction that allows consumers to be anywhere, yet nowhere. Rapid prototyping, visualization tools, and direct linkages between computer-aided-design and
manufacturing tools, are changing the way consumers can radically customize products. CAD/CAM technologies are streamlining the process of manufacture, changing the model from mass-produced similar objects, to mass-produced dissimilar objects. Industry is moving in the direction of on-demand manufacturing, where need and production strives for organic balance. In the not so distant future, more and more products will become custom-built, design will become a critical selling point, and design tools will change the way we realize visions of home.

A critical analysis of Modern methodologies regarding the design and construction of houses will frame an argument and historical narrative into which new homes can be located. In looking at changing demographics, new market trends, and emerging computational technology, we will construct a design framework for creating new homes. We can discover a new model for making places by learning lessons from the past, assessing the present and looking to the future. It is my hope, and the impetus behind this research, that we can develop a model that is affordable, multivalent, expressive, and identifiably post-industrial.

If the post-industrial house is to be anything, it must first be an extension of human freedom. Any time the ability to be openly creative or expressive of identity is impeded, freedom is withheld, and it against such strains that a new architecture must direct its energy. The aesthetic and social oppression latent in any suburban development is veiled by obscure notions about middle class happiness and security, and above all, the economic interests of the individuals responsible for creating these vacant landscapes.

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9 The first part of the thesis considers the attempts by avant-garde and modernist architects to breech the housing market with new and expressive vision of architecture. As we will see, they were largely disillusioned and were not able to steer the course of housing development in any significant manner. Can we introduce modernist design principles into the home, or are we to face the same absurd uphill battle that they fought?

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US Census Bureau
Cost of housing has gone up steadily, as have the standards of living.
The shape and appearance of our communities has been handed over, nay stripped away, by institutions of power and control that leave little recourse for the average homebuyer to live creatively. Those who reject the system move back to the inner city and rehabilitate defunct industrial landscapes in the hope of salvaging self-respect, independence and a sense of community. The post-industrial house must not become yet another vehicle of oppression in the hands of a corporate elite, but a catalyst for social and political change able to liberate the architecture of home. It is to these ends that this thesis has been geared, and constitutes a commitment to expanding the role of the architect into the realm of housing.

Here I am referring to the concentration of artists and other un-suburbanites who move into typically desecrated areas of cities and bring them back to life. Of course, once big business sees the value of such property rise along with the quality of life, they are fast to move in and drive the artists to yet another forgotten part of the city. The procedure is nothing short of treachery.
PART 1:

The Modern-Industrial Home

"By slow degrees the building sites will become industrialized, and the incorporation of machines into the building industry will lead to the introduction of standard components; house designs will change, a new economy will be established; the standard components will ensure unity of detail and unity of detail is an indispensable condition of architectural beauty...Our towns will lose the look of chaos which disfigures them today. Order will reign and the network of new roads, from an architectural point of view, will provide us with splendid views. Thanks to the machine, thanks to standard components, thanks to selectivity, a new style will assert itself."

-Le Corbusier, l'Esprit Nouveau
The first part of this research is a critical survey of twentieth century modern-industrial houses, with an emphasis on American projects. This survey serves two primary objectives: (1) to set the stage, both historically and technologically, for the introduction of the post-industrial house, and (2) to abstract fundamental criteria for adaptable domestic architecture. Three primary characteristics can be traced through each of the examples looked at: the use and consequences of experimenting with new building materials; the opening of the house to space, light and air; and the conscious creation of a new style of architecture. We will gauge the success and failure of various housing systems in order to understand what principles should be incorporated, augmented, or rejected in the design of new homes.

Beginning with Le Corbusier's and Ozenfant's avant-garde rejection of the Beaux-Arts tradition with the publication of L'Esprit Nouveau in the early 1920's, the survey will trace the influence of the International Style to American soil, where architects such as Richard Neutra and Albert Frey began a Modernist tradition which continued until the late 1960's, with the break up of the Arts and Architecture Case Study House legacy. Along this trajectory we encounter a diverse gamut of modernist architects who sought an expression of industrial society in the form of the house. These expressions will also be examined in the context the Century of Progress International Exhibition that took place in Chicago in 1933. International exhibitions were a popular outlet for experimentation and public persuasion, where new ideas concerning the house were showcased and promoted. Visions of the industrial house were displayed at a number of fairs over the years, including, The International Exposition of Modern Industrial and Decorative Arts in Paris (1925); the Weissenhofsiedlung Housing Exhibition in Stuttgart (1926-7); the Modern Architecture exhibit in New York (1932); The Century of Progress in Chicago (1933-4); and Futurama, at the World's Fair in New York (1939-40). Concurrent with the American import of the European avant-garde aesthetics and the predominance of world Expos was the work of Frank Lloyd Wright that dealt explicitly with pre-manufactured systems and industrial materials. His con-
crete textile-block houses in Hollywood, and his later post-war Usonian houses are both relevant examples. Also included in this discussion are two housing systems that attempted to breach the housing market with factory-produced industrial homes by Walter and the Lustron Company. As we will see, both attempts failed dramatically, but provide insight into how and why such endeavors were ill fated and never made headway in the market. Excluded from this survey are houses that may have used new materials in construction, but neither exploited the material structurally nor sought to express qualities of being part of an industrial culture. Sears Roebuck kit-houses from the 1920’s are thus excluded, as are the post-war mass-production efforts of Levittown and the subsequent suburban developer type home.

Each of the projects selected were conceived as structural, social, and spatial expressions of a new cultural paradigm rooted in industrial production. By and large, these houses were designed by avant-garde architects who shared a common vision of arriving at something expressly Modern. That is, they sought solutions that were in tune with contemporary systems of production, economics, aesthetics, and technology\(^1\). The availability of mass-production goods, new modes of transportation, artistic

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\(^1\) To get a sense of the spirit of the age, one can look to the Italian Futurist, Sant’Elia: "WE must invent and rebuild \textit{ex novo} our Modern city like an immense and tumultuous shipyard, active, mobile and everywhere dynamic, and the modern building like a gigantic machine...The House of cement, iron, and glass, without carved or painted molding, extraordinarily brutish in its mechanical simplicity, as big as needs dictate and not merely as zoning rules permit, must rise from the brink of a tumultuous abyss; the street which, itself, will no longer lie like a doormat at the level of the thresholds, but plunge storeys deep into the earth, gathering up the traffic of the metropolis connected for necessary transfers to metal cat-walks and high speed conveyor belts." Quoted from Banham, \textit{Theory and Design in the First Machine Age}. Page 129

The image reminds me of a recent infiltration into the current mega project under the city of Boston: what has been called \textit{The Big Dig}. 

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experimentation, and the maturation of theoretical science were but some of the key forces that influenced the design and construction of modern-industrial homes. Nominalization, rationalization, and standardization had all been adopted by industry in the form of management control, factory efficiency, and profit maximization. In the house, exploring such concepts was an attempt to bring the standards of living into synchronization with processes of production. Minimum standards of living (existenzminimum), which included the provision of adequate light and air, were developed. For the avant-garde architect, the vision of the mass-production house became emblematic of a new era, and the impetus behind a new style of architecture. However, as innovative as these new styles may have been, they never took hold in the mass-market of residential construction, and have come to represent overly zealous styles for elite patrons. 

Recognizing that the modern-industrial home has not made significant headway in the housing market, one is tempted to ask, “Why then, are we even examining such houses?” To answer this question I refer to a quote by Nietzsche that Charles Jenks elucidated on in his book *The New Moderns*: “He who must be a creator in good and evil—verily, he must first be a destroyer, and break values into pieces. Thus the highest evil is part of the highest goodness. But that is creative goodness. Let us speak thereon, ye wisest men, however bad it be. To be silent is all the worse; all unuttered truths become poisonous. And whatever will break on our truths, let it break! Many a house hath yet to be built. Thus spake Zarathustra.” The implications of this text in

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2 See Welch, *Modern House*. Welch comments on the character of the new business class that emerged during the 1920's and 30's, asserting that ‘style’ was a principle way distinguishing a new class wealthy individuals: “Modernist’s foremost exponents, such as Mies van der Rohe and Le Corbusier, operated in European countries whose rollercoaster economies could throw up a millionaire as easily as they could mass unemployment. These clients, who neither belonged to, nor were welcomed by, the aristocracy, reasoned that if the new rich could not join the aristocracy, they could at least beat them. What better way to do that than through fashion?” Page 8

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3 See Jenks, *The New Moderns*. Pages 33-34
relationship to modernist architects cannot be understated if we accept that the project of Modernism was to wipe the slate clean, creating a tabula rosa for a new and emerging culture grounded in the capitalistic spirit of mass-production and the enlightened consumer. A new economy created opportunities for middle class citizens to participate in an industrial culture, and hence begin the process of restructuring social and aesthetic organizations.

Le Corbusier sought to create houses for a new class of individuals, a class composed of intellectuals, engineers, scientists, accountants, and the like. In effect, he believed the educated and progressive mind (we might even call them supermen) was in need of a new style divorced from the past. A style defined by a constant state of destructive newness found in the tools and products of an industrially driven commodity culture. In the end, Le Corbusier was premature in his assessment, as his society was still largely composed of the Marxist class dichotomy between the bourgeois and proletariat. The houses that he built catered to a then elite class. Today that class has become the majority. Today, more than ever, the intellectual class has the power and the authority to define a new style and redress the problems that Le Corbusier noted back in 1923: "The various classes of workers in society today no longer have dwellings adapted to their needs: neither the artisan nor the intellectual." That the modern-industrial house did not have a widespread stylistic influence may simply be an indication that the time had not yet arrived for such a revolution. The following survey will thus create a framework into which the post-industrial house will fit, and in doing so help make the case that the time has finally arrived to answer Le Corbusier's infamous maxim: ARCHITECTURE OR REVOLUTION.

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4 Le Corbusier. *Towards an Architecture*. Page 269
A NEW SPIRIT:

The development of modern-industrial homes was a logical extension of the industrial revolution. Engineering advancements in structural systems, public utilities, distribution of power and goods, and transportation all influenced the emergence of modern detached dwellings. It should be noted that while the industrial revolution began in the middle of the eighteenth century, the houses to be discussed were all built in the twentieth century. The development of the detached, Modern house truly was a new phenomenon that sprouted in early 1900's. The modern kitchen and bathroom, heating and insulating against hot and cold, air conditioning, soundproofing, termite and vermin proofing, fire proofing, and waste disposal systems did not make significant headway in the home until the early 1900's.

As it were, Modernism made its initial appearance in institutional architecture, not in residential architecture. Architectural expression became explicitly industrial with the construction of the large span exhibition halls, train sheds, bridges, and monumental icons, such as the Eiffel tower and Gallerie des Machines, which came to define the triumphs in Nineteenth century architecture. New and increasing degrees of industrial production continued to influence architecture, and by 1904, with the publication of Tony Garnier’s Cité Industrielle, the foundation was set for new experiments in residential architecture.

The streamlining of production, best exemplified by Henry Ford’s assembly line (1909), gradually shifted the workforce from unsalaried manual labor, to positions of management and greater social mobility. New types of businesses created new labor markets, which in turn created a type of consumer. In fact, between 1870 and 1930 there was a 71 percent increase in the number of occupational designations in the United

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2. Sigfried Giedion, Building in France Building in Iron building in Ferro-concrete.
States. Ford introduced the automobile into popular culture and paved the way for the development of decentralized suburbs, and increasing demand for detached, low-density housing.

The Modern house, while essentially a product of the Twentieth century, was indebted to innovations and principles developed by the previous generation. In the Nineteenth century, iron came to define a new art and science of construction (architectonics). Stone and brick were fundamentally compressive systems; where iron was able to resist both tension and compression. As a result, the age-old heaviness of the arch was lightened and made into a latticework of thin skeletal members. The structural and expressive capacity of stone first realized in the simple arch, and pushed to its utmost limits in high gothic architecture, was transposed into a new material and given a new character. Unprecedented limits of space and structural articulation were explored. While initially slow to take hold in a deeply embedded classical tradition, iron could ultimately never be tamed to behave as stone. Beginning with Henri Labrouste's Bibliotheque Ste-Genevieve in Paris (1838) and culminating in England with the Crystal Palace (1851), the use of iron in construction revolutionized architecture and created new horizons. The Eiffel tower, the Gallerie des Machines, the graceful concrete bridges of Millart, were all indications of a new era of architectural expression.

Just as wrought iron had opened the door to new types of architecture, the development of steel and reinforced concrete also began the process of supplanting old methods of construction with new materials and new conceptions of form and space. At first, literal transpositions took place, in which concrete simply replaced heavy timber,

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3 Rowe, Modernity and Housing. Page 9
4 Frampton, Modern Architecture: A Critical History, Pages 18, 35
as in Thomas Edison's house, or August Perret's apartment building. Supplementing old materials with newer materials, but retaining stylistic conventions it rapidly became pastiche and incongruent with the tenants of the European L'Esprit Nouveau (the new spirit).

In the words of the master (yes, Le Corbusier) himself:

"The history of Architecture unfolds itself slowly across the centuries as a modification of structure and ornament, but in the last fifty years steel and concrete have brought new conquests, which are of a greater capacity for construction, and of an architecture in which the old codes have been overturned. If we challenge the past, we shall learn that "styles" no longer exist for us, that a style belonging to our own period has come about, and there has been a Revolution."

With the exploitation of the structural integrity of steel and reinforced concrete came new types of space in turn created new possibilities for living. An open architecture filled with abundant amounts of light and air became possible by taking advantage of the physical properties of both steel and concrete. The formal result was a shift in typology from heavy masonry walls, to post and beam frames with lightweight infill panels and large spandrels of glass. The use of the classic modern rolled steel frame became a standard detail.

Gone from the equation of housing was trial and error type construction, those methods of creating vernacular structures. Adherence to eclectic classical styles were eroded and replaced by a new found faith in technological innovations in the fields of engineering and science. Scientific objectivism, transmogrified into "functionalist" theories of form and function, was imported into the architectural vocabulary and became

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5 Le Corbusier, Toward a New Architecture. Page 7
6 One can find the steel section in practically all modern achievements in architecture. By the 1950's, the steel section could be found in all types of buildings from schools to suburban homes.
the impetus for utilitarian architecture. In most cases, this strict analogy between architecture and science created buildings that lacked a human scale, had little or no character, and were aesthetically neutral\(^7\). In fact, as we shall see, it was this strict adherence to functional, "minimal standards of living", that fueled some the marvelous failures of industrial housing (the Lustron house, Operation Breakthrough). The counter point to functionalism can be found in the principles of organic architecture developed by Wright and to a large degree present in the great icons of the International Style.

The homes selected based on their use and expression of industrial materials, and the resulting spatial, organizational, and aesthetic character achieved. The discussion is chronological, beginning with the European avant-garde movement that spawned the International Style, ending with a brief account of the current state of industrial processes. Excluded from this survey are the many examples of houses that used new materials in construction, but consciously chose not to address the aesthetic and spatial properties of new materials and processes. Also excluded is the post-war suburban prototype that began in Levittown and has now contaminated the suburbs of American cities. Subsequent chapters will address in more detail the ills of suburban houses and will outline the reasons for new (post-industrial) solutions.

\(^7\) Here I am referring to the widespread acceptance of the efficient "modern" office complex, a form that has done little to extend the social and aesthetic project began by the early Modernist architects. Reynar Banham cites the U.N. Headquarters building as seminal influence in creating the bleak and empty character prevalent in corporate institutions: "The U.N.(building) has all too often served as an instrument of Big Power politics and of grinding bureaucratic rutinism, lightened by small veins of honest good will and humanity, and the architectural style which it canonized has seemed all too often to serve the same less-than-human purposes, as the great conglomerate corporations and bureaucracies of the world imitated its glass-tower style in their own headquarters and branches." *Theory and Design in the First Machine Age*, Page 9
The provision of more freedom in design, construction, and ultimately living, is the goal of any well-conceived architecture. As Neil Jackson states, “The Modern house was able to conquer impossible hillsides, provide flexible and expandable spaces, and respond to the strong lines and delicate detailing of the Modern movement. More than that, it was able to fit comfortably within a tradition of constructional clarity, common to both Classical and Gothic architecture.”¹ The association that Jackson makes between Modern architectural systems and Gothic/Classical principles is supported by Hitchcock and Johnson’s 1932 assessment of International Style architecture: “Modern architecture has nothing but the healthiest lessons to learn from the art of the further past, if that art be studied scientifically and not in the spirit of imitation. Now it is possible to emulate the great styles of the past in their essence without imitating their surface.”² The ‘essence’, to which Hitchcock and Johnson are referring, is the spatial consequence of architectonics that is independent of any applied decoration or stylistic convention.³

A new “machine” aesthetic materialized as rationalized and highly aestheticized solutions, eventually causing a radical break in formal as well as functional design principles associated with house. This break, sought a new objectivity (neue Sachlichkeit) which they found in the machines and mass-produced objects of their time. Essentially, the Modernists felt it imperative that architecture be an expression of the times: just as the new vehicles, tools, and objects were undeniable proof that a new epoch had begun, so too should architecture participate in the revolution. This spirit was canonized by Le Corbusier’s seminal work, *Vers Une Architecture*, first published in

¹ Jackson, *The Modern Steel House*, Page 5
² Hitchcock and Johnson, *The International Style: Architecture since 1922*, Page 19
³ Hitchcock and Johnson argue that the International Style is founded on three fundamental principles: (1) the conception of architecture as volume rather than mass, (2) regularity rather than axial symmetry as the chief means of ordering design, and (3) the elimination of arbitrarily applied decoration.
1923.

The European art and architecture movements of the De Stijl, the Bauhaus, and Atelier Le Corbusier, imported concepts, processes, and aesthetics found in industrial models of production and engineering and then exported symbolic and metaphoric variations of this theme. Their formal gestures sought to elucidate the changing experience of both time and space inherent in a culture undergoing constant flux. Different from the engineering monuments of the previous century, the Modernists of the 1920's had a naive, if not contrived theoretical connection between architecture and machinery. This disjunction can be described as a physical incongruence between machines and space. A machine is a self-contained device that performs specific operations, either autonomously or at the hands of a user. Machines are not inherently spatial or aesthetically derived, and moreover, people use, rather than inhabit machinery. Thus, the problem of architecture, and specifically that of the house, is not comparable with the problems that confront the design of an engine or some other tool. Where industry was genuinely concerned with inventing and struggling with unprecedented forms and objects, the house was an age-old project, with perhaps the longest history of precedents of any man-made venture. Yes, the house can employ new techniques and materials; yes it can accommodate all manners of new machines; and yes it should compliment technological innovations. But this is not to say that the house is a new machine, or a previously unimaginable technology. The effects that technology has had, and will continue to have on architecture cannot be under estimated; nor can they be truly isolated. One thing is certain however: technology creates opportunities to explore alternative modes of being in the world, and the house, as a tactical as well as strategic vessel, is a primary expression of these opportunities.

The International Style achieved an organic quality that was distinct from a purely functional architecture. The plans and volumes crafted by the best of the European Modernists effectively grew out of a clear relationship between the use of space and the
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The Concrete Frame. The use of reinforced concrete was the material of choice for a Modernist, 'International style' home. Ironically enough, the style was often imitated using conventional wood framing.

Form of space. Or as the architect F.R.S York stated in 1934, "We discover, when we have observed and become familiar with the machine, and the standard machine product, that it has a balanced harmony, clean planes, exciting curves, and powerful shapes—a beauty that is neither classical beauty, nor that of artistic craft. It rather approaches the biological beauty of a flower or animal bodies."4

Sigfried Giedion follows the development of the emerging modern epoch in an evocative bullet point style in his 1928 book entitled: Building in France, Building in Iron, Building in Ferroconcrete. The book traces the origins and architectural consequences of the use of iron and concrete in building construction. Lightweight, rapidly assembled, exhibition halls of the late nineteenth century are represented as logical extensions of the properties of iron, a material that Giedion describes metaphorically as both the muscular tissue and skeleton of a building. Likewise, he follows the evolution of reinforced concrete and eventually begins a discourse on the house. Giedion provides an explicit mention and documentation of modern house projects that include work by Tony Garnier, Robert Mallet-Stevens, Le Corbusier, and August Perret, among others. Like Le Corbusier, Giedion saw the house as an essential catalyst for social and spiritual awakening, a vehicle through which the masses could become liberated. Where large-scale public space such as factories, schools, exhibition halls, etc. were the focus of an earlier generation, Giedion saw the house as the next essential development of Modern architecture. He states:

"To the present generation falls the task of lifting the HOUSING PROBLEM out of individual dilettantism and pseudohandicrafts and onto the level of industrial standardization through the most precise and thorough consideration of housing functions. The future generation will once again prefer large construction projects. But this time variable...

4 Yorke, The Modern House. Page 14 This is an unapologetic Moderist guidebook to the "new style" of residential architecture that spread across Europe, England and the United States between 1920-1934.
buildings, open to all possibilities and closely connected with means of transportation. With elevated and underground trains, airplanes, waterways. Comprehensive relational coordination of all means."

The text precedes a documentation of houses designed and executed by Le Corbusier, Robert Van 'T Hoff, and Henri Sauvage. In each case, new construction materials were employed and given form in respect to the material. In each case, the use of steel in the construction system allowed for the qualities that typify the modern house to emerge: open systems that provided increased presence of light, space and air. As Giedion imagines, the modern house is wrought from industrial practices, given an economy and efficiency found in mass-produced objects, and satisfies a larger social need for improved living conditions.

There are two key concepts in Giedion's short paragraph that are of particular interest regarding the post-industrial dwelling: One is the concept of variable building, and the other is that of connected, or interconnected systems of mobility and transportation. The concept of variable buildings begins to parameterize the house beyond the strictly aesthetic, or abstract interpretations that frequently accompany modernist houses. It also suggests a divergence from strict functionalist concepts that were expressly invariable. The increasing mobility and adjustability that modern innovations were affording, in both structural systems and the growing consumer market, were influencing the spatial and functional requirements of the home. The automobile, new appliances, large panes of glass, and other industrially manufactured building materials came together to create a unified response to changing social and economic opportunities. In terms of connectivity, Giedion imagines highly connected landscapes of houses, industry, commerce, and leisure. In today's terms, connectivity is still a requirement, but has grown to include mobile computing and communication networks.

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5 Giedion, Ibid. Page 167
The post-industrial house will have similar aspirations as those outlined by Giedion, but have specific responses to contemporary technologies. In terms of variable buildings, Giedion imagines landscapes that are formally diverse and dynamic; a world defined by constant interpenetrations of space, ideas, and events. For Giedion, the house, as part of the dynamic social order, should be expressive of the interplay and mixture of art and technology present in the culture.

Giedion continues his discussion of the Modern house with an analysis of Le Corbusier's villas and housing projects, singling out the idea of interpenetration: an oscillating ensemble of surface, lines, volumes, and mass. He sees the standardization of cleanly delineated parts as means of achieving interpenetration, which consequently established a new spatial/social context for the free expression of art and science. He comments emphatically,

"Normalization and standardization are the only expedients for the liberation of architectural vision! They play no other role in architecture than the vacuum cleaner or the washing machine in the average household: to free the mind for better things! Details lose their disastrous tyranny only when they are standardized. In every sense it can be understood for the future: there are no more details, there is only an ensemble!" \(^6\)

Le Corbusier is well known for the bluntness and often cryptic arguments found in "the most influential, widely read and least understood of all the writings of the twentieth century": his first published book, *Vers une Architecture*. The book is a complicated story of construction and straightforward design, an idea given prominence by Hermann Muthesius at the turn of the century.\(^7\) Le Corbusier interprets the machine as a vehicle for straightforward design, as a tool able to realize precision, accuracy and

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\(^6\) Giedion, Ibid. Page 179

\(^7\) Jenks, *Le Corbusier and the Tragic View of Architecture*
universal harmony. His arguments establish an architectonic and poetic basis for design, stating that, "The purpose of construction is TO MAKE THINGS HOLD TOGETHER: OF ARCHITECTURE TO MOVE US." For Le Corbusier, the dual nature of architecture as both construction and poetic sentinel was critical in defining his system of architecture. He addresses the role of systems throughout a limited history of architecture, going so far as to relate the Parthenon to the racecar, the Aeretheum to the airplane. In this way, Le Corbusier demands an architecture that is not so much a revolution, but a continuation of an age-old process of construction and design that is grounded in the union of technics and art. Le Corbusier will assert, that architecture is a matter of harmonies, it is "a pure creation of the spirit", and in doing so, embraces a fundamental contradiction inherent in the machine aesthetic: the machine, while utterly powerful, cannot create a new architecture. Rather, the machine must be harnessed and used as a tool for "pure creation"; use of the machine for any other purpose would prove devastating for architecture and culture as a whole.

His principles elucidate the engineer's aesthetic morality, and are then transposed onto architecture itself. Le Corbusier approaches a structural rationalism, but ultimately adopts a more artistic articulation of form through revealing harmony between buildings and their landscape, subtlety of light and texture, artificiality of symmetry, and movement through space. His idea was that architecture should project itself into the world through the interplay of mass and space, light and dark, complexity and simplicity, consequently generating promenades of deeply poetic architectural experiences. The development of this system emerged in Le Corbusier's early housing solutions, which began with the Dom-ino theory (1914) and was realized at Pessac in 1925.

Le Corbusier published 'Five Points for a New Architecture' in 1926, twelve years after conceptualizing a system that had all the seminal characteristics of his new archi-

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8 Le Corbusier, Ibid. Page 19
The Dom-ino house. A system of concrete columns and floor planes, the concept was driven by a desire to fully recognize and take advantage of the properties of reinforced concrete slabs and columns. Reduced to a mere structural skeleton, the Dom-ino house reveals a flexible and open system in which both the façade and interior treatment is ambiguous and undefined. The plan and elevation are liberated, open to limitless possibility. As a system, however, one questions its validity. Given that so much is left to interpretation, it becomes impossible to gauge the system in the absence of other necessary systems. How well the concrete slab interfaces with other systems becomes a critical design and performance issue that is left obscured by the overly open concept. Only in late designs, where the system becomes filled in can we assess its functional and aesthetic potential. Still, we should remember that Dom-ino was the birth of an idea: an initial concept about architecture engaging new building materials and methods and creating a new sense of freedom in space.

The Pessac housing project represented a significant turn of events in Le Corbusier's career: at last he was able to physically realize the ideas that had been brewing for years within the pages of *L’Esprit Nouveau*. Built for a working class community as a series of mass-produced single-family units, the project was designed as a flexible system of standardized cubes, reinforced concrete beams, and ribbon windows. It was an adaptable, five-meter module framework able to change as users cycled through the community. The houses were arranged in what appears to be an organized compositional grammar that imparts a sense of variety and spatial complexity to the project. At the same time, there is an utter uniformity in detail and construction technique used throughout all the houses. All the parts were standardized to the fullest extent possible.

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9 Le Corbusier described the system in *L’Esprit Nouveau*: at Pessac we are working exclusively with standardized components: the same windows everywhere, the same staircases everywhere, the same doors, the same heating, the same 5m x 5m or 2.5m x 5m concrete cells, the same kitchen and washroom equipment, the same dressing rooms...Standard components are letter, and in a particular way, you have to spell out the names of your future house owners."—quoted from Boudon, *Lived-In Architecture*. 
mass produced components that could be arranged in various compositions, which in the end proved to create a diverse and provocative system. Use of repetitive, standardized elements in varied combinations emphasize the fundamental dichotomy between industrial production and a poetic architecture.

Pessac, like most mass housing projects of the period, had its problems. Le Corbusier wanted Pessac to be an innovative solution to the housing problem, and thus sought to use unconventional construction machines and processes. Giedion describes the unprecedented process: "Machines fabricate the insulating cinder blocks and the concrete beams on site. I have personally seen the Ingersoll-Rand Company’s ‘cement gun’ (the concrete canon) spray forth a 100-meter wall in just a few days." As impressive as the concrete canon system was, it proved to be a difficult and cumbersome tool; and Giedion is quick to remind us that the machine "aroused the resistance of the workers to the point of sabotage". In addition, standardized parts did not always fit neatly into their precut places, contractors had to rethink their traditional roles and techniques, and schedules proved hard to keep. While often a problematic process, it was valuable as a learning tool for Le Corbusier, for he was able to truly experiment with his ideas before moving onto his later villa designs.

In trying to impart meaning to otherwise empty mass-produced products, we see an attempt at Pessac to negate the fascist character of mass production by presenting it as a system that can become unique and individuated, rather than homogenized and alienating. Pessac is well known for its adaptive characteristics and ability to reflect the user rather than the architect. As Charles Jencks suggests, Le Corbusier ended up, "admiring the way personalization was destroying his own architecture." The architecture, while derived from an explicit aesthetic and constructional system, was free to change, even to point of annihilation. In it’s adaptability, Pessac is a successful

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10 Giedion, Ibid. Page 170
11 Jenks, Ibid.
After the completion of Pessac housing, Le Corbusier was to revisit the structural concepts of the Dom-ino system and apply them to his late 1920’s houses, concretizing his ideas into five design principles:

1. Use of piloti to raise the building off the ground, creating a *Piano Nobile*. (The basement is eliminated.)
2. Provide roof garden and patios by means of flat roofs and terraces.
3. Adopt the ‘free plan’, where interior walls and treatments are independent of the structural column grid.
4. Adopt the ‘free façade’, where the envelope of the house is free to be rendered as solid, void, or screen.
5. Use of long horizontal bands of windows for even and abundant distribution of natural light.

The use of these ‘Five Points for a New Architecture’ became indicative of a new style of construction that developed through the use of modern industrial building materials. Reinforced concrete, rolled steel window frames, sliding glass windows, asbestos and cement roofing material, linoleum, and other such materials provided the vocabulary with which to construct modern systems of space, form, and order. The use of curving interior walls and bright contrasting colors were also used, and in many ways distinguished Le Corbusier’s houses from other contemporary ‘International Style’ buildings.

At the Villa Stein (1927) and Maison Cook (1926) we can see Le Corbusier’s principles clearly applied. In each case, both tectonic and poetic concessions are made that elucidate the system Le Corbusier was working to create. The houses are tectonic in
their formal derivation from structural and material properties, while achieving a poetic quality in the deliberate and careful use of light, massing, sequencing of space, and geometric variety. The interplay of curving forms within an orthogonal framework is used to express the freedom of the plan. Service cores and utility spaces are typically found concealed behind the curvatures, generally located on the lower level, while living spaces occupy second story rectangular volumes. As a precedent, the Citrohaus project of 1923 can be cited, while the Villa Savoye, a wealthy county retreat, was to become the standard reproduced icon of Le Corbusier's 'new architecture'.

Le Corbusier cites the use of regulating lines in *Vers une Architecture*, as a means of achieving a unity of proportions between plan, elevation, and human scale. We need to remember that innovation is at once technical and aesthetic: it connotes new methods of thinking that dramatically, as well as subtly, affect the processes involved in human existence. Thus, innovation cannot be considered as a merely technical or aesthetic evolution, but rather as a synthesis of both aspects of design that come together to form new and (hopefully) improved conditions for being in the world.

Le Corbusier's contribution to the modern house has proved significant and generative. With the Dom-ino system, Le Corbusier defined an era of building style that put an emphasis upon volume—space enclosed by thin planes and surfaces—opposed to the suggestion of mass and solidity; regularity as opposed to symmetry or other kinds of obvious balance; and, lastly, dependence upon intrinsic elegance of materials, technical precision, and fine proportions, as opposed to applied ornament. Above all, Le

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12 Etlin describes the 'five points' as a new architectural system that extended beyond the concept of style: 'They are realizations not merely of a 'style', but rather of an 'architecture' based upon a new 'architectural system'. With this notion of system in mind, it is possible to see how Le Corbusier went beyond his contemporary practitioners of the International Style to give his architectural system a richness and complexity generally absent from other buildings.' *Frank Lloyd Wright and Le Corbusier: Th Romantic Legacy*. See Pages 13-25
Corbusier's architecture exceeded the functionalist tendency to over simplify the problem of housing. Rather than minimizing architecture to a purely mechanistic science, he created buildings that responded to deeper human emotions and needs. Use of color, geometric playfulness, light, and gracious volumes all contribute to the value of his work as an architectural system.

13 Hitchcock and Johnson, Ibid.
RICHARD NEUTRA AND ALBERT FREY:

The International Style, and Le Corbusier's design principles, were introduced to the United States through the architects Richard Neutra, Rudolph Schindler, and Albert Frey, and officially welcomed in 1932, with the opening of the exhibition, *Modern Architecture*, at the Museum of Modern Art in New York City. At the exposition three American house projects were featured, Albert Frey and A. Lawrence Kocher's 'Aluminaire', Richard Neutra's Lovell 'Health House', and Frank Lloyd Wright's 'La Miniatura'. Wright's work will be looked at in a subsequent chapter, and constituted a very different architectural system than either that of Frey or Neutra. Both the Frey and Neutra were distinct in their ideas about modern architectural systems, yet invariably tied to the aesthetic edge of the European Modern movement.

Richard Neutra's arrival to the United States in 1923 preceded Albert Frey's by seven years, giving Neutra a unique position as a European architect on American soil. Neutra's departure removed him from the new Modern European architecture just as it was being born. At the time he left, the Bauhaus was in its infancy, Le Corbusier was largely a theoretician, and the "Modern House" had yet to truly see its day. Neutra left Europe before the physical realization of any truly Modern dwellings, but the ideas surrounding such manifestations were well disseminated and had been postulated for years. He carried with him the images of Theo van Doesburg, Mies van der Rohe, DeStijl painting, and cubist theories about space and time. Remarking on the qualities Neutra abstracted from the principles being established in Europe, Sigfried Giedion, in the introduction to *Richard Neutra Buildings and Projects*, writes:

"Material and structure concentrate upon the planes, glass walls, reinforced concrete... here is the hovering, overhanging, horizontal roof slab, the transparency of ribbon windows, the radiating into landscape. All these elements, just as in cubism before, were not the invention of one individual, but grew out of the core of this period. These elements of new space-conception formed the artistic luggage which Neutra took to America.24"
His removal at an early period of development freed him to define his own struggle, and to come to terms with his European sensibilities in the context of the United States.

From the standpoint of systems, Neutra had definite goals. His residential projects consistently utilize pre-fabricated elements and industrial materials to generate a spatial vocabulary. From the lavish Lovell Health House to his modest plywood houses, Neutra sought to use innovative and modern materials as vehicles for a new architecture. Like Le Corbusier, he wanted to give the dwelling new architectonic substance. As Neutra proposes in an essay on the ‘Foundations of Buildings’, “The architecture to secure our future will be light, elastic, flexible, with built-in climate.” While we can see traces these desires in all of his designs, perhaps the more interesting of his designs were in some of his un-built experimental projects, each of which display highly innovative notions about the dwelling and industrial prefabrication. Three of his experimental systems are outlined: A proposal for a new type of adjustable, structural steel foundation system, the One-plus-Two Diatom houses, and an all plywood house.

As early as 1923 Neutra was designing innovative houses made of steam hardened infusorial earth composition, or what came to known as “diatom” houses. The earliest sketches show a free plan and composition similar to Frank Lloyd Wright Prairie designs of the previous decade. At the same time, he was developing a new type of steel-foundation anchorage system. (Diatom) Homes were to be supported on pre-fabricated adjustable foundations that would allow pre-fabricated building units to adapt to any number of site conditions. By replacing the conventional concrete or brick foundation with a series of large steel joints, site work was to be minimized dramati-

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2 Neutra, ibid. Pages 118-129
3 Originally published in Architectural Record, January, 1934
cally, and the time taken to prepare a site for other prefabricated components would have likewise been reduced. In theory, no site work was necessary, as the footing were entirely adjustable, making the house more or less something like a lunar Lander. The house was removed from the horizontal earth plane, held suspended by a mast system that would transfer the building load into the metal foundation anchors.

The One-plus-Two Diatom Houses of 1926 is an extension of the diatom and mast idea proposed in 1923, and Neutra appears to have dedicated more time to detailing and understanding the actual construction system of these houses. The houses had three parts: a main living quarter, garage, and a separated bedroom unit. The main living space was pierced through with three metal masts that support the whole building by means of adjustable metal cables. The walls were made of an earth substance hydraulically fused with mortar and cast into panels for ready built erection. As a system, the One-plus Two Diatom functions as a detached single family home that can be altered quite easily with the introduction of additional bedroom units or the reinterpretation of the garage or existing structure into other desired functions. The house as an adaptable system capable of growing surfaced as a principle in these houses.

The system is aesthetically controlled by a fascination with the horizontal plane and its abstraction as a removed element in the landscape. Differing from the houses Neutra built in the 1940’s and early 50’s, (Tremaine Residence, the Desert House) the Diatom system does not organically meshed with the landscape. This characteristic became the dominant association with manufactured homes as they have emerged over the years: self contained, mobile boxes that can be placed virtually anywhere. Where the Diatom system differs from the manufactured home in its structural system, the spatial character is little different than that of ‘double-wide’ trailer home. The structure was undoubtedly unique, only to be seriously developed to greater detail by Buckminster Fuller (Dimaxion) and George Keck (House of Tomorrow) in the early 1930’s. Spatially, the house is interesting in its arrangement of indoor and outdoor rooms, and the distribution of program elements with its framework. The use of large
glass planes and earthen wall panels opened the house, and perhaps save it from being little more than a manufactured box.

The Plywood Model House, of 1936 was a small, weekend retreat with a compact and free flowing plan. It is explicitly orthogonal with a flat overhanging roof characteristic of Neutra houses. Design sensibilities found in most of Neutra's work are present: the open floor plan, semi-outdoor living space, informal dining and living areas, provision for cross ventilation, integration of landscape, strong horizontal planes, and inclusion of pre-manufactured furnishings. The construction consisted of prefabricated plywood panels applied over an insulating shell of noncombustible slabs of pressure hardened petrified wood shavings. That's right, petrified wood. Use of petrified wood was a means of locating the house within a larger geographic context; had Neutra not been building in the barren Californian landscape, he undoubtedly would have experimented with different types of regional materials.

Ultimately, Neutra never built houses at the scale of mass production; rather, he incorporated mass produced products throughout all of his designs. His early works in pre-fabricated panels, the expression of the structural steel frame, and the low horizontal profile of free-flowing space was picked up en force in the post-war Case Study House program, which we will be looked at in more detail in a following section.

Albert Frey has a similar story, one that began with his early interests in emerging

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4 Neutra. Ibid. Pages 127-129
5 Neutra designed four Case Study Houses, #6, #13, #20, and #21. #20 was the only design actually built. (1947-48)
European aesthetic theories, was nurtured at the Atelier Le Corbusier, and was realized in his best known contribution to the modern-industrial house: the infamous Aluminaire. Built for an indoor Exhibit in 1931, the Aluminaire was divorced from any real site. At its core, it was a freestanding expression of European design principles, and is perhaps the most faithful rendition of a compact Le Corbusier villa to be built in the United States.

Built almost entirely of aluminum, the house exhibits the 'Five Points toward a New Architecture' in a typically Le Corbusian fashion. The main living spaces are pulled off the ground plane with slender piloti, and located in a double height piano nobile. Ribbon windows wrap the building, giving it a light and airy quality, while also serving to dislocate the building from any specific site constraints. It was designed for rapid assembly and disassembly with the notion that it could be relocated at the whim of the owner. Outdoor patios were provided, and the plan was left relatively "free". The six aluminum columns support an aluminum frame structure that is minimally insulated with asbestos sheathing. Spatially, the home is compact, neat, and well organized, includes a shower that projects out into the double height living space, and has space for cars to park beneath the first floor.

As interesting and well conceived as the Aluminaire appears, it had no influence on the development of single-family home construction. At best, the aesthetic character was imitated in the form of steel-cage office buildings clad in pre-fabricated metal sheets and aluminum window frames. Given the corporate appropriation of this type of system, it is not hard to imagine why people are not building homes in a manner similar to the Aluminaire. The idea of living in a house that resembles a suburban office building was destined to end in failure. Albert Frey, of course could not have fore-

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5 Frey worked for Le Corbusier from 1928-1930, during which he worked on the Villa Savoye, and was thus thoroughly versed in Le Corbusier's architectural principles.

7 The Aluminaire now resides at the New York Institute of Technology, Ipswich New York. Remarkably, the building has survived three erections/disassembly sequences.
seen such a predicament, and cannot be discounted for his attempts to introduce a new architectonic vocabulary into the American context.

More influential than the actual built work by Frey and Kocher was their joint control over the publication of *Architectural Record*, from 1928-36. With Kocher as managing editor, and Frey at his side, the duo was able to freely expound their visions of industrially produced homes for modern living. Fundamentally, their design criteria were oriented around the improvement of performance, durability, and economy, rather than any specific aesthetic or stylistic concern. This is a radical break from the European Avante Garde, who rarely, if ever, specified design guidelines based on building performance, rather than an implied machine-like functionality. Worth mentioning here is a checklist published in April 1933, which, by and large, is still applicable to construction today. The bolded text are concepts that are not present in most houses built today, but are worth exploring in the context of the post-inustrial house:

"Structural system with prefabricated units joined together by pressure or bolts. Materials for walls that effectively exclude heat, cold, dampness and sound. Weather tight joints throughout, not subject to deterioration. Exterior surface of walls should be hard and durable, requiring little or no maintenance. **Wall units of uniform size to permit interchange of parts.** Interior wall surfaces suited to cleaning with commonly used cleansing powders and soap. Structure resistant to corrosion and attack by insects and fungi. Absence of projections that gather dust. Dry construction. Lightweight. Minimum flashing. Wall structures capable of housing or attaching heating, wiring, and lighting pipes and ducts. **Parts capable of replacement and addition. Erection and installation of parts by unskilled labor. Possibilities for demolition and re-erection on a new site.** Resistant to earthquake and heavy wind pressures. Lightening proof. Fireproof throughout. Possibility for natural or applied color. Windows of uniform and standard size, permitting maximum daylighting and control of fresh air and sunlight. **Roof drainage through center of house for economy of required piping and to prevent freezing.** Soundproof partitions. **Interior partitions flexible and capable of varied arrangements. Closets, cabinets, and equipment as units.** Minimum cost upkeep and construction."
While the typical developer house can meet most of the performance criteria mentioned in the list, some are left out for obvious reasons. Of particular interest and relevance to post-industrial dwelling are the mention of interchangeable and removable parts, the concept of closets and storage as detachable units, and the integration of services into pre-fabricated components. These will be examined in more detail in subsequent chapters that deal with the design criteria for new houses.

Both Neutra and Frey were innovative designers that gave expression to their architecture by utilizing industrial materials. However, their reliance on singular materials, as in the Plywood house, and the Aluminaire, proved to also be limiting factors, and contributed their lack of public acceptance in the housing market. Precut plywood has certainly become a standard building material, as are aluminum windows, however these materials are sheathed over by layers of siding and/or paint. Public sensibilities have yet to endorse raw exposure of manufactured material, preferring decorative coatings and faux historical inferences, over any resemblance to mechanized production. The irony, of course, is that even the Styrofoam moldings and pre-stamped composite siding are undeniably the products of industrialization, and far removed from anything that could be considered ‘handicraft’. For modern architects like Richard Neutra and Albert Frey, the expression of material was an essential part of their design vocabulary, and means of creating a new style. Beyond the expression of style, they believed that the taking advantage of the precision and cost-reducing nature of milling pre-fabricated components could consequently lower the cost of housing. Just as other manufactured modern conveniences became cheaper and more accessible because of industrialization, so too could the modern house. In the end, such ideas had to face a market controlled by developers who had no intention of pushing the market and taking unnecessary risks.  

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8 Jackson points to reason why modern design systems cannot penetrate the market: “Developers and contractors will not, on the whole, build something which they don not think will sell. They perceive what they think the public wants and the public buy it because they are led to understand that this is what they should have. it is a circular and strongly contained argument.” The Modern Steel House. Page 226
In 1933 Chicago was host to the Century of Progress world fair: an exhibition that promoted the technological innovations and showcased the development of modern, industrial American values. The exhibition grounds covered an enormous lakeside space and were composed of hundreds of buildings and exhibits. Included at the exhibition were a slew of experimental "homes of the future" that promised an optimistic view of living in the wake of depressed social and economic conditions. Each of the homes built for the exhibition engaged different levels of mass-production and each was employed an innovative building material. Distinct brand-name materials were expressed at each house, which subsequently determined the names of the houses: Masonite, Stran-Steel, Lumber Industries, Rostone, Armco Ferro-enamel, General, Tropical, Century, Brick Manufactures, Design for Living, Owens Illinois, and the Crystal house. The home planning commission set four principle guidelines for houses to be built at the fair: durability, convenience, livability, and cost-efficiency. As a result of these practical guides, the fair was less aesthetically overbearing and political than earlier European Exhibits.

Various companies and architects tried their hand at creating aesthetically pleasing homes meant to integrate modern technology with futuristic design and, most importantly, be affordable. Some were more or less traditional in appearance, others more unconventional. All were well equipped with modern appliances and conveniences, open living/dining spaces, modern bathrooms, and provisions for heating and cooling. The focus was on technology and machines in the home, more than the creation of a new style or aesthetic. In all, industrial sponsors built twelve houses that loosely aspired to imitate European styles, but generally lacked any spatial intrigue. More than anything, the homes were an experiment in commercial advertisement and product show-

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1 Boyce. Keck and Keck. Page 35
2 Specifically, the 1925 International Exposition of Modern Industrial and Decorative Arts, Paris; and the Weissenhofsiedlung, Stuttgart 1926-7
casing. Frank Lloyd Wright declined to participate in the event on the grounds that, "the whole performance was petty, strident, and base, and nothing happened except gesture and gaudy—sometimes bawdy—self-indulgence" 3 Stripped of all ornamentation, the model homes had neither basements, nor any obvious resemblance to a conventional wood-framed house. They were different, but not in a particularly satisfying way, as they relied heavily on the use of one primary product, which failed to address the house as a system of diverse materials and parts.

The most intriguing houses were designed by architect George Fred Keck, who was responsible for the self proclaimed "House of Tomorrow" and the "Crystal House" (sponsored by Century Homes, Inc.). Both houses utilized and expressed structural steel frames and large expanses of glass. The House of Tomorrow was a twelve-sided house held aloft by a centralized steel mast with living quarters on a piano nobile, and came complete with an aircraft hanger on the ground floor. The Crystal house was an ecto-skeletal open box with open floor plans and adjustable ventilation louvers on the inside. Both homes presented a vision of future living totally alien to the American public. Putting the primary living quarters on the second floor (piano nobile) was a new approach to residential design unfamiliar to average home consumers. Similar to Frey and Kocher's Aluminaire, the houses had a European, mechanistic look to them, achieving a literal transposition of 'machines for living' conceptualization into built form. As a machine, however it proved to function in less than desirable ways, and ended up being more or less an expose of the use of glass to create an entire building envelope.

Keck's houses were inexpensive utilitarian building systems that represented a sophisticated and innovative use of material and became a clear expression of a technological

3 Wright. Architectural Forum 59, July 1933
1.5.2
The House of Tomorrow. George Fred Keck

The House of Tomorrow. It took a mere forty-eight hours to erect, and was entirely pre-fabricated. The use of the 'cage' meant that no exterior walls were load bearing and could thus be left totally open to sunlight and air. The houses did suffer from overheating however. Even though the House of Tomorrow was one of the first houses open to the public that used central air conditioning, it proved impossible to keep cool. Keck had essentially built a greenhouse, and the home was closed to visitors in the summer months.

1.5.3
The Crystal House. George Fred Keck

Both the House of Tomorrow and the Crystal house can be read as logical extensions of Buckminster Fuller's concept of Dymaxion living, in which the house is a self-contained machine that is maintenance free, and hence a liberating force in society. In terms of the expression of a steel frame the house was unprecedented, and became an inspiration to later Case Study architects. As one critic put it, the Crystal house "Combined the ultimate constructivist aesthetic with truly progressive structural and material technology. Designed as a symbolic evocation of life in a "machine age", technology and content were fused together in this structure at a level of intention and realization promised but never realized in European or Russian architecture of the period."

The open and unrestrained floor plan suggested that the home could be reconfigured easily to suit the individual tastes and needs of potential inhabitants. However, no information is available that suggests if the house was ever experimented with in this regard. Keck continued to develop industrial houses throughout his career, but never explored the use of steel frames to the extent that he did in 1933-4. We can only speculate that the image was incompatible with aesthetic sensibilities as well as overall performance criteria current in the housing market. Like Philip Johnson's Glass House in New Canaan Connecticut (1949), the Crystal House and House of Tomorrow

4 Boyce. Ibid. Page 44
5 Jandl, Yesterday's Homes of Tomorrow. Page 134
6 Progressive Architecture 62, February, 1981
were more for display than anything else.

If anything can be culled from the Century of Progress Exhibition, it is that the use of a new material does not, in itself, imply a good architectural solution. The all metal Stran-Steel house used a prefabricated steel frame and had the 'classic' modernist steel window frames in place, however, the plan still feels restrictive, the formal massing banal, and the house offered no opportunities for change over time. This is one of the reasons that prefabricated homes never took off: in so far as they simply imitate an existing conventional style, rather than improve upon it, then reasons for buying a manufactured home rapidly dwindle to zero. If prefabricated houses are to be successful they must offer significantly more advantages and opportunities than the conventionally framed home.
Throughout the career of Frank Lloyd Wright, one finds a persistent relationship between industrial materials and his concept of Organic architecture. As early as 1901, with the publication of The Art and Craft of the Machine, Wright sought to incorporate machine processes into his architectural vocabulary and methodology. As Frampton states, “Wright attempted to derive authentic ornamentation from the process of fabrication, irregardless of whether this entailed the mechanized manufacture of basic building blocks or synthetic assembly of prefabricated modular timber elements straight from the mill.” In his concrete textile-block houses of the 1920’s and his later work on Usonian houses, Wright utilized the capacity of prefabrication to realize some of his most interesting residential architecture. The economic value of using prefabricated components was also explored, although more so in his Usonian Houses. The textile-block house were essentially one-off homes for a few wealthy individuals, while the Usonian Houses were intended to provide affordable solutions to post-war housing shortages.

In 1923, Wright built his first of four concrete textile-block houses: the Alice Millard residence, also known as La Miniatura. The house, which was showcased at the 1932 Modern Architecture Exhibit in New York, was in rather stark contrast to the homes by Neutra and Frey. Similar to his European contemporaries, Wright was working to give new expression to industrial building products. Wright explored concrete-block, and sought to exploit the inherent flexibility of a repetitive tectonic system. The development of the concrete block had been in the works since the Midway Gardens project a decade earlier, where cut stone panels were applied to vertical surfaces and inscribed with geometric patterns. However, at Midway, the blocks were not integrated structurally, and remained mere application panels. In California, Wright took

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1 Wright. Frank Lloyd Wright: Writings and Buildings. Pages 57-58
3 Incidentally, La Miniatura was excluded from the book published for the exhibition by Johnson and Hitchcock
full advantage of the plasticity of concrete, realizing that it could be imprinted and thus
given depth, articulation, and most importantly, the ability to weave itself into a structural
system. For Wright, the system, was a perfect mix of the art and science of mechanically
produced building elements: "I finally found a simple mechanical means to produce
a complete building the way the machine made it, as much at least as any fabric need
look. Tough, light, but not "thin"; imperishable; plastic; no unnecessary lie about it
anywhere and yet machine-made, mechanically perfect. Standardization as the soul of
the machine here for the first time may be seen in the hand of the architect, put squarely
up to imagination, the limitations of the imagination the only limitation of building."**4
Wright was clearly working with the concept of a woven architecture when he built the
homes. By expressing the concrete as a woven system of construction Wright drew
attention to the screen like nature of the enclosing membrane, which is further reinforced
by a sub system of reinforcing steel that knits the entire system together. Because
fabric has the ability to be articulated, it suggests a relationship between the use of
block and a woven image that tells a story. For Wright, the story of his California houses
is told not so much in the details but in the total composition and formal massing.

Wright was to build a series of four concrete-block houses in southern California,
each exploiting his system and defining a new, and perhaps more appropriate re-

gional aesthetic. Concerning the concrete block and its use in the hills of southern
California Wright wrote, "The concrete block? The cheapest (and ugliest) thing in the
building world. We would take that despised outcast of the building industry-the con-
crete block-out from underfoot or from the gutter—find a hitherto unsuspected soul in it—
make it live as a thing of beauty—textured like the trees. Yes, the building would be
make of the "blocks" as a kind of tree itself standing at home among the other trees in its

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4 Wright. *Frank Lloyd Wright: Writings and Buildings*. Page 225
own native land." What the textile-block offered was a tectonic language: a syntax of construction that if creatively applied could yield any number of variations. The blocks also satisfied the duel function of providing interior and exterior finish, which eliminated the need for plaster and other labor-intensive finish work. An air space between two parallel block walls provided the necessary thermal break to keep the houses cool in the summer and warm in the winter.

Wright continued to develop the use of standardized concrete blocks in later houses, but as Terry Patterson writes, "a majority of his block buildings were built predominantly of plain faced units. Plain faced units are within the nature of block, but they fail to demonstrate the uniqueness of their substance among masonries." Thus, we may conjecture that the poetics of construction is not inherent in the materials used, but must be extruded and discovered through time and creative interpretation. The use of standardized building material can be either banal or intriguing depending on how it is interpreted and integrated into the composition of a house. For Wright, giving material an expressive character was fundamental to his organic theories of architecture. The properties of each material have configurations and surface qualities that characterize the substance and its associated technologies. In this respect, Wright relied on the nature of the material to define the form, as is evident in both his concrete-block houses and his later Usonian Houses.

The Ennis House of 1924, like La Miniatura, emphasizes the blocky nature of the construction, itself appearing as an abstracted rocky outcropping that has the feeling of age and ruination. It has been suggested that Wright was influenced by Mayan ruins, and I believe justly so. (The Hollyhock House is excellent example) The Mayan culture had a rich building tradition and like many ancient civilizations applied rich decorative motifs to their architecture. But beyond the decorative qualities, it is the

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5 Wright. *Collected Writings* Vol. II. Pages 276-7

6 Patterson. *Frank Lloyd Wright and the Meaning of Materials*. Page 132
use of local materials and consequent deterioration and plant over-growth that seems to consume such buildings. Of course, concrete is not necessarily an indigenous material, but it does have the malleability to be cast in shapes and forms that seem relevant to specific environments.

His concept of the Usonian Houses is another example of a system of construction that was used to create rhythm and spatial complexity. They were intended to be inexpensive and offer a viable alternative to conventional housing. The construction system was based on three primary concepts: organizing grid, construction technique, and heating system. In all, twenty-six Usonian houses were actually constructed, which is a far cry from his visions of a Broadacre City sweeping across the vast plains of America. Even so, his system was a novel integration of building materials and worthy of mention.

Usonian homes used an integrated wall system of wood board and battens that proved less complicated than his previous concrete-block houses. Like the concrete-block houses, the walls required no additional treatment and created an organizing horizontal grid to which all doors, windows and built-in furniture aligned. The system was intended for a middle-class citizen on a tight budget, and Wright made every attempt to reduce the number of components needed to construct a house, while still allowing variety and distinction between individual homes. The driving principle of a Usonian house was its ability to generate a unique response to both the site and client needs. As Wright believed, "There should be as many different houses as there are people." Each of Wright's Usonian homes was different, yet adhered to a consistent construction and organizational grammar. The floor plans were based on a two-foot by four-foot grid in earlier homes, and a hexagonal pattern in later designs. A tight weave of both vertical and horizontal elements was thus achieved, that was kept from being overly

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7 Sergeant, Frank Lloyd Wright's Usonian Houses. Pages 16-21
8 Sergeant. Ibid. Page 40
simplified by breaking up the plan and opening the living room to the kitchen. Floor to
ceiling operable windows were used throughout the designs, as was the use of clerestory
windows to bring in more light and add geometric complexity to the overall composition
of the houses. The grammatical character of the Usonian style becomes more evident
the more one looks at the designs. Wright was able to develop a grammar that allowed
for variation precisely because he had the opportunity to do so. In the previous examples
we have examined, the architects did not experience the same freedom to experiment
with as many variations as Wright did, and were therefore unable to expand their design
vocabulary.

Defining the Organic as an essentially architectonic method of designing and con-
stricting is made evident in Wright's use and composition of constructive elements.
As we have seen, there is a strong emphasis placed on the assemblage of parts and
their ability to achieve a unified structure. Wright's material decisions were affected
by certain abstract principles about beauty; it was after all the beautiful that Wright
sought to realize in his organic architecture.

Relative to the post-industrial house, we should be aware that Wright's sensibilities to
light, spatial organization, and massing are all important architectural characteristics
that need to be incorporated into a meaningful design process. We are not looking to
simply premanufacture houses, but to use premanufacturing with the intent of creat-
ing salient architectural works. How materials are assembled, both practically and
aesthetically will need to be considered in detail, if any progress is to be made.

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9 Wright. *In the Cause Of Architecture*. Architectural Record, March 1908, Pages 155-222
1.6.4

Usonian House Plans. The distinctive style of Wright’s plans is evident when comparing several variations. Plans typically have two primary axes with bedrooms in one wing and an open living space in the other. The Plans are (opposite) Brauner House, Garrison House, Newman House, and the Rosenbaum House (this page).
Richard Neutra was a well-established pioneer of modern architecture when the opportunity to work on a new, highly spirited architecture journal was made available to him in 1942. The journal was *Arts and Architecture*, and the editors of the publication intended to present and encourage new trends in residential and industrial architecture. That Neutra was involved in the magazine comes as no surprise when one flips through the disintegrating pages of post-war journals. Low, single story horizontal houses made of prefabricated parts turn up again and again. The influences are obvious, and the examples of "innovative" houses are deliberately selective. Of course, Neutra wasn’t the only influence of the times, and a study soon ensued that would capture some of the decades most interesting and innovative homes in flashy, dramatic detail. A new chapter in the evolution of the industrial-modern house had begun.

Editor of the magazine, John Entenza, outlined the Case Study proposal in his January 1945 issue. The premise was to initially gather eight notable architects from around the country to design and build eight houses in Southern California. The houses would make use of as many or as few manufactured products as the architect desired, and would be conceived as a means of visualizing the "post-war house". Implied in the Case Study project was an attempt to bring practical innovation to the public at large. As Entenza states in his first announcement of the Case Study project,

"It is important that the best materials available be used in the best possible way in order to arrive at a "good" solution of each problem, which in the overall program will be general enough to be of practical assistance to the average American in search of a home in which he can afford to live."

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1 The initial eight architects were: J.R. Davidson, Richard Neutra, Spaulding and Rex, Wurster and Bernardi, Ralph Rapson, Whitney Smith, Thorton Abell, Charles Eames, and Eero Saarinen.

2 Entenza, *Arts and Architecture* January 1945
The Case Study Houses project began just as the war had ended, and new socio-economic conditions prevailed. The houses were to be expressions of the modern man in relation to war-wrought technologies and materials. Entenza, always the optimist, wanted nothing short of a "good life" scenario for everyone, where the comforts of modern amenities would be matched with an equally comfortable home that was fundamentally Modern—that is to say, expressive of the times.

World War II created a widespread manufacturing context in America. The country realized its potential to produce massive amounts of machines in limited amounts of time. As a result, the factory became a nexus of creative impetus necessitated by the demands of war. A devastating reality, the war affected virtually every American living in the 1940's. Not only were countless lives lost to horrors and treacheries of the war, but also entire communities were fractured, and a great rebuilding would be required to stitch the American social fabric back together. The American public was not prepared to simply go on living as they were, during and before the war. No, indeed, they deserved better. They had fought and died for a free world, and they wanted a tangible reward. If the country could rally to produce airplanes and bombs by the thousands, then why should it not be producing refrigerators, electric ranges, and gleaming new modern houses? Thus began the total infusion of machines into middle class strata of society. Modern conveniences became increasingly affordable, the suburbs began to spread, and government subsidized mortgages were encouraging returning veterans to go buy new homes.3

3 Welch. Modern House. "In the US, the small modernist villa became and has remained the preserve of the rich; immune from and unattained by either the repetitiveness of social housing or the narrowmindedness of suburban tract housing. Proof of both the American lack of social commitment and the conservativism of its middle classes rests with the results of the Case Study House programme." Page 8
For John Entenza, this created an opportunity to present the world with real projects for modern living. He wanted to direct the course of the small American house toward the use inexpensive industrial materials, the blurring of indoor and outdoors space, the open floor plan and feeling of being contemporary. A five-acre tract of land the Pacific Palisades was purchased and became a testing as well as proving ground for new experiments in dwelling. The first wave of Case Studies were certainly the most interesting, and include work by Neutra, Koenig, Ellwood, Saarinen, Soriano, Eames, and Davidson. By 1967, when Arts and Architecture was dismantled, the housing market was largely dominated by land developers and big business. The fight for the single-family house was lost, and the social project of delivering a new architecture to the masses was effectively made obsolete. By the 1970's, the architect had become completely disenfranchised from the housing market; a so-called modern house became a luxury item for the rich, not a new standard of living. Thus, industrial-modern houses became one-off instances of eccentric style, deep pockets, and heavy architectural fees.

Of the twenty-seven houses either built or proposed during the projects seventeen-year lifespan, Charles Eames’s #8 and Pierre Koenig’s #22 have stood out more than any other. They are perhaps the most widely published of the Case Study houses, and have become symbolic of the entire venture. #8 is a dramatically different break from the other houses; while #22 is a hyper-simplified, yet dramatic use of steel and breathtaking vistas.

Like all the Case Study houses, the Eames house makes explicit use of standardized industrial materials. The spatial and formal gestures are entirely different than the typically Neutra-like planning found throughout other Case Study designs. The plan is not a sprawling array of low horizontal planes filled in with enormous amounts of glazing, but a compact and vertical box with smaller windows that put more of an emphasis on the frame rather than the openness of the glazing. The Eames house thus demonstrates a different sensibility to materials. It also but relates well to the site as well as the artistic lifestyle of Charles and Ray Eames. The façade composition is simple and elegant, creating a complimentary pattern to the surrounding woods. In fact, the structural sys-
tem becomes a secondary, if not incidental fact that supports a much broader goal of creating an environment that is connected to both the site and the individuals living in the house. As Neil Jackson writes, "Rather than being intrusive, the long lines of the steel frame and profiled metal roof complement the twiggy eucalyptus trees which line the cliff-top meadow site". The Eames house made no assumption about what average family needs were: it was designed around the particular needs, and whims, of Charles and Ray Eames. Thus, the house may not be appropriate for all types of family organizations, but it does suggest limited amounts of spatial adaptability.

Case Study House #22, the Stahl Residence, is set on a cliff overlooking Los Angeles. Built in 1959, it was Koenig's second of five case study houses. The site is stunning and made more so by the strong use of horizontal lines and absolute reduction of surface. Walls of glass create a transparency and lightness that make the house virtually disappear. The structural system, composed of only two standard H-sections, metal decking and a concrete slab, has a similar goal found in Eames house: that of augmenting the conditions of the site. The use of steel creates spatial and expressive opportunities that would be impossible with other materials. The Stahl house is less about the use of prefabricated parts than the matching of desire with an appropriate material. The same system would make little sense in a cold climate or suburban lot.

That Entenza's larger fantasies did not come about was probably no surprise to any one who worked for him. Still, while the Case Study Houses did not radically affect the rest of the country, in California he was able to open the doors to a larger audience and gain public acceptance of experimental design. Esther McCoy notes that

"The banks (in California) had previously taken the view that a house with glass walls open plan, no dining room, kitchen facing the street, flat roof, and slab floor was a poor investment and had no resale value.

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4 Jackson, *The Modern Steel House*. Page 50
That all Case Studies Houses were excellent investments is proved by the prices at which they have been resold (90-125 percent above the original cost)⁵

Changing the attitude of banks was a radical step forward for the project, and will always be a hurdle for new styles to jump over. The degree to which a new style is allowed to flourish is inextricably tied to economic conservatism concerning the shape and appearance of the American single family house.

The Case Study architects enjoyed the creative freedom to be experimental and connected to a self-motivated arts movement. They approached the house as vehicle for social change and artistic expression. "As the history of the Case Study program shows us, even the most excellent designs for individual houses cannot, in themselves, lead to sweeping changes required to house the majority of American is new ways. But as the legacy of the program suggests, innovation in housing across cultural, social, technological, and economic boundaries is still urgent."⁶ What we can learn from the efforts of the project is that continued research into materials and building technologies encourages the designer to reconsider methods of conceiving space that improves the quality of living. The spirit that drove the Arts and Architecture endeavor is perhaps the most valuable lesson from the period, for it speaks to an essential ingredient needed to continue the process of rethinking the house. Without the sense of urgency and desire to see the house emancipated, the project of the Modern-industrial house, and now the post-industrial house, would be long buried and forgotten.

⁵ McCoy, Case Study Houses 1945-1962. Page 10
⁶ Hayden, Blueprints for Modern Living. Page 210
The use of open web steel joists are left exposed, revealing the simplicity of the construction system. This type of construction typifies contemporary retail and commercial work, but has not found its way into the residential market.
At the beginning of his keenly entitled book, "The Evolving House" (1936), Albert Bemis states, "Only a new conception of structural design can satisfy the requirements of modern engineering and industry. These requirements include mass production, speedy assembly, scientific and social efficiency, and facile marketing". Over the past one hundred years architects, builders, and corporate interests have tried to bring the mass-produced, machine crated home to the market. From an economic standpoint, the factory produced home was supposed to stake its claim in success of modern industry. Discounting the mobile home industry, no single system of industrially produced houses has stood the test of time. In an appendix to the Evolving House, Bemis cataloged over fifty companies that had developed prefabricated house systems. While many of these ventures were ambitious, and in the "spirit of the times", they lacked a clear sense of architectural balance. i.e. most systems did not address a cohesive set of interrelationships between technology, aesthetics, space, function, composition, and personal expression. Even if conventional houses lacked such interrelationships, one was not likely to accept a model that did not offer a better organization, aesthetic, and utility.

The failed attempts to industrially manufacture homes are well summarized by two examples from the late 1940's: the Lustron All Metal Dream Home, and the General Panel Packaged Home. Lustron was financed and conceived of by an industrialist, while General Panel was the vision of two great architects; neither of them were either archi-

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1 Sigfried Giedion, writing about the Genral panel system comments, "Gropius' and Wachsmann's Packaged House System, with its carefully worked out designs of standardized building components, is in the direct line of future development, especially in its concentration upon the production of easily transportable and easily assembled house types. Nevertheless it has had no financial success. Why is this? In large buildings in the United States often eighty percent of the construction consists of standardized prefabricated parts. But their use for small private houses meets with considerable psychological difficulties." Walter Gropius. Page 76
tecturally or financially successful. In both cases, all production took place in factories and product was shipped as a ‘kit of parts’ for rapid on-site erection. The Lustron had a totally fixed plan and offered no flexibility, while General Panel was intended to be a highly adaptable, limitless means of creating space with a system of universal connectors.

Lustron was the vision of Carl Standlund, a well to do vice president of a porcelain enamel company that created baked on enamel-steel panels for gas stations. His goal was to produce a cheap, efficient, mass-produced house that would address the growing housing shortage at the end of WWII. His solution, intended as an inexpensive factory-production system, was designed to meet high-volume demand for housing. Consequently, he won support from the Federal government in the form of huge low-interest loans, and within a year had secured enough capital to finance a twenty-three acre factory and begin a nationwide marketing campaign. The actual machinery for producing the houses was tremendously elaborate and expensive, and produced an exorbitant number of parts (3,000) that had to be skillfully assembled on-site. Architect Carl Koch described the system:

"I remember...our first tour through the premises on a motor wagon, gazing at the acres of machinery. Even by American mass-production standards, it was an impressive layout. With everything going at once, the factory used as much electric current as Columbus proper. The houses themselves started at one end as rolls of steel, bar stock, or other elementary shapes and from there were moved by conveyor; sliced punched, stamped or otherwise bashed; welded riveted, bolted as the case might be; or sprayed and backed—finally issuing at the other end as packages of 3,000 component parts, loaded on special trailers and ready to go."2

2 Quoted from Jandl, Yesterday’s Homes of Tomorrow. Page 193
Clearly, the system was not well thought out. It is remarkable to imagine that so many machines were designed and engineered to produce a product as thoroughly banal at the Lustron house.

The problems with the Lustron system were many-fold, but can be traced back to the initial inception of the design. From the very beginning Standlund set unreasonable constraints. That the home should be entirely made of metal was problematic from start to finish. That assembly required skilled labor was bound to cause mistakes, loss of time, and ultimately money. The singular floor plan and arrangement of pre-determined bookshelves, cabinets, and vanity mirrors was overbearing and not able to change as needs might change. And above all, given the huge amount of capital invested in building machines and production lines, that the actual manufacturing process was so rigid and essentially impossible to change seems absurd. A contradiction in manufacturing was miraculously achieved: the product, while hyper-manufactured, was totally un-designed. As a result, the failure significantly undermined any confidence that the American public, and more especially lending firms, had in pre-fabricated building systems.³ It was not until 1962, with the government-sponsored project, Operation Breakthrough, that any serious attempts were made to engage the potential prefabrication of dwellings.

Walter Gropius and Konrad Wachsmann faced similar issues when trying to implement the General Panel packaged Home concept. Conceived as a panelized method for building houses, the system relied on a hyper-designed universal connection, which became the obsession of Wachsmann for nearly a decade. In principle, all panels, ceiling and roof included, were to be locked into place with a single, standardized metal joint. In the same way that Standlund reduced the problem of the house to a single

³ Herbert, The Dream of the Factory Made House. Page 313
material, Wachsmann had reduced the problem to a single connection. In the end, the Lustron Corporation only produced some 2,500 houses, a far cry from their original goal of manufacturing 25,000 homes a year.

General Panel had as many limitations as did the Lustron, and also failed to engage the wide range of industrially produced building products already on the market. (Mass-producing the Eames house would have probably been easier than either General Panel or Lustron in this regard.) The module was based on the meter, rather than the foot, which made the system all the more alienated from the American building industry. Aside from the technical and dimensional limitations, the theoretical concepts of Gropius and Wachsmann were quite interesting and relevant to our discussion. As Herbert notes, "it was conceived in much more flexible terms. Here it could be described and open-ended. It did not postulate a standard design, nor did it even envisage a standard set of house designs. It was intended to generate a very wide range of design options, which could not, in fact should not, be predicated in advance." A great principle, that to my mind was not achievable in the already constrained properties of the panels; i.e. the use of a metric module, only ninety degree-angles, a single aesthetic character, and an overall limited number of panel types.

The total number of General Panel homes did not exceed between 150 and 200, which caused the factory that had been built in California to be shut down. As with any manufacturing venture, profits are a function of a sustained output volume, which the General Panel Corporation was unable to establish. Modeling the fabrication of houses after automobile production proved to be inadequate and unfounded. The dream of the factory built house was actually a financial nightmare that never came to fruition. As Herbert writes, the factory produced home faces many difficult to manage variables:

"High production costs leading to escalating prices; difficulties with organiz-

4 Herbert, The Dream of the Factory Made House. Page 313
The Packaged House. Houses were factory-made and shipped to site by truck, for erection by trained crews.

The success of a modern-industrial house in the housing market has yet to see its day. If General Panel and Lustron had approached the design differently, perhaps their system would have worked, however, the constraints, both technically and aesthetically, kept the enterprises from making any headway. When you add poor management to complicated and incompatible architecture, you are bound to end up with a disaster and broken ego. When conceiving the post-industrial house, which will rely on prefabrication and factory production, it will be critical to take into consideration compatibility and stylistic diversity. A single solution to the housing problem will likely solve no problems at all. A system needs to be developed that can attain a great many stylistic conventions, while also being precision manufactured and prefabricated.

Herbert. Ibid. Pages 312-313
The Packaged House. Drawing by Knorad Wachsmann showing the limited types of wall components. In all, there were less than twenty types of components for walls, ceilings, trusses, and floors.
CONCLUSIONS:

Architectural systems engage industrial production at many different levels, however, not all systems can be considered integrated, innovative, or expressive of unique characteristics. Even fewer systems achieve all three of these properties at the same time. The house and design methodologies that we have explored each tend toward extreme expressions of ideology and aesthetic style. With the European avant-garde, abstract Cubist and De Stijl paintings were as much an influence as ocean streamliners and industrial factories. Innovation in the use of new materials was ideologically imbibed with a sense that a new era had arrived, and consequently given stylistic overtones. Regarding the exhibition homes from the early 1930's, the emphasis shifted from aesthetics to home appliances and the use inexpensive materials that looked manufactured. Frank Lloyd Wright was very interested in achieving an organic unity between new materials, client needs, and site connectivity, but was never able to mass-produce significant volumes of houses. And when architects did attempt to enter the mass-production housing market, they were met with financial disaster. Factory-produced homes were seldom cheaper (though they always claim to be), did not provide any significant customization options, lacked aesthetic appeal, and were associated with factory production. With the Case Study Houses, the emphasis was less on mass-production of houses, and more about the use of mass-produced materials to build a house. The homes do not have the claustrophobic feel of manufactured housing, and yet similar materials are employed. The Case Study Houses began to open door to a vast market of possibilities concerning home architecture. While notable architects were expressly chosen to design the houses, there is a suggestion inherent in the Case Study Program that anyone could build their own Case Study House. Not only that, but they could afford to by taking advantage of pre-manufactured building supply. The influence, though limited aesthetically, is defi-
nitably being played out to some degree with the explosion of do-it-yourself building supply chains, and availability of vast amounts of industrially produced building product.

The industrial-modernist house became a symbol of a changing aesthetic and social sensibility, but was unable to complete the task of breaking down age-old associations with the traditional home. The result is all too familiar: what began as an attempt to revolutionize housing via mass-production, became the driving force behind cost and time saving corporate real estate investments. Mass-production became synonymous with cheap and affordable, rather than expensive and durable. Thus, the use of traditional styles in suburban developments has become little more than a clever way of masking the inexpensive and cheap quality of homes. If mass-production developer homes were expressed as such, then the housing market would likely collapse and simply return to old styles rendered in plastic bricks and composite shingles. The industrial-modern aesthetic is decisively *not* a masking of industrially produced products, but a creative expression and interpretation of such materials, using space, form, and composition. Of course, function is woven into this equation, but was not the overriding design principle.

What we are left to contend with is the fact that architects have not been able to create aesthetically interesting, custom designed modern homes for the masses. The value that we abstract from modern masterworks always seems distant and removed from the realm of possibility when considering mass-production. After all, the houses that we most appreciate are those examples that do not lend themselves to mass-production not meager budgets. Clearly, who would not want to live in a home as elegant

*The Seagrams Building.* The Modern aesthetic became widely accepted by corporate institutions, which served to further stimatize the expression of industrial materials in the home.
as Wright's Falling Water? Who would not build a Villa Savoye on a nice five-acre plot of land? In truth, these homes are beyond the reasonable means of cost effective mass-production. However, this is not to say that compositional grammar, geometric complexity, and a direct relationship between house, site, and occupant cannot be accomplished that takes advantage industrial processes. As we have seen, the failure of factory-made housing resides in the fact that they never offer the consumer a significantly better alternative. Rather than revolutionizing housing, manufactures have simply sought to provide a slightly cheaper imitation of an already cheap and ill-conceived model. There is no sense in pursuing a system that does not begin to improve the quality of living. The modernists, well aware of this, struggled to make a significant contribution to shape and appearance of housing, but were ultimately confined to a typically elitist circle of intellectuals, artists, and bourgeois businessmen, that consequently put their residential architecture outside of mainstream socioeconomic systems.

**1.9.2 Mondrian Dress.** Modernism became a style, and less a social movement concerned with emancipating the home. It became a statement of being "in style" for those who could afford it.
PART 2:

The Post-Industrial Home

"We are being driven into an indivisible life process. We see life more as a moving yet indivisible whole. The boundaries of individual field blur. Where does science end, where does art begin, what is applied technology, what belongs to pure knowledge? Fields permeate and fertilize each other as they overlap. It is hardly of interest to us today where the conceptual boundary between art and science is drawn. We value these fields not hierarchically but as equally justified emanations of the highest impulse: LIFE! To grasp life as a totality, to allow no division, is among the most important concerns of the age."

Sigfried Giedion, Building in France, Building in Iron, Building in Ferroconcrete
INTRODUCTION:

The second part of this thesis is an outline of a process for the design and construction of post-industrial houses. The process is informed by an analysis of sociological and economic changes viewed through the lens of United States demographics and changing trends in service as well as product markets. The information age has created opportunities never before available to connect information, people, products, and tools in a comprehensive, open source format. Complex and sophisticated organizations of information facilitate high levels of connectivity across disciplines. The syntax and grammatical relationships between objects in the computational world are defined by programming languages, which have in turn allowed vast numbers of machines to communicate coherently across the globe. In a similar fashion, the post-industrial house will be a system of parts that exist within a framework of relationships and a complex array of variables that are connected across a matrix of data. The home will be a product of a coherent language: an expression of architectonic relationships and user-defined variables. The goal then, is to propose an architectural vocabulary for the construction of houses, and from this vocabulary, discern a set of variables that allow clients to rapidly customize their environments.

The proposal calls for a web-based design tool that provides architectural services to clients looking to buy a new home. Three key elements are involved in the process: (1) a user interface, (2) parametric models that can be augmented by shape grammars, and (3) a construction system that can be manufactured in a factory and shipped to the building site. The interface will be the client side portal into the design process and the place where variables are adjusted and options explored. The backend programming will use client input to define spatial and aesthetic vocabularies that then generate parametric models. Variables are subject to the constraints of a construction system that redefines both the structural shell and interior walls of a home.

The process of designing the post-industrial home is entirely dependent on the widespread distribution of interconnected computers. A series of steps, all within the
framework of a computational platform, begins with the construction of a client values and needs, includes interactive parameter setting, 3-D visualizations of various home designs, experiments with stylistic grammars, and concludes with a fully finished construction model that would be fired off to a manufacturing facility for custom fabrication. From the definition of individual room sizes and heights, to the specification of hardware for cabinetry, the design tool will act as the primary mediator of information concerning the design and construction of new homes, with the intent of finding an "best fit" scenario organized around the sensibilities and needs of individual clients.

The essence of a post-industrial society is defined by the ability to control information. To control information, knowledge is required, and knowledge implies specialized intellectual training. As jobs become more specialized, so does the knowledge required to perform such jobs. In this way, while information is said to be everywhere, only trained specialists know how to use specific information in a knowledgable way. Thus, products are often the result of highly specialized labor industries that are utterly unintelligible to the average consumer. Electronic products are a good example of such a phenomena. The computer, VCR, television, video camera, etc, are all highly sophisticated devices that proliferate our lives, yet we would be hard pressed to claim any sort of understanding as to how or why such devices function. All the consumer is required to understand is the interface—that is, how to operate and make use of the product. When I change the television station with a remote control, I am not concerned with "how" the device works, only that it works and works well. In the same vein, the post-industrial design tool will be supported by specialized knowledge concerning architecture and construction, and the client will only need to know how to use the tool. Thus, the tool will assume clients have no knowledge about architecture, yet they will be able to design well-conceived homes. The key will be developing an intuitive interface that allows individuals to specify needs and desires, and then to be able to make adjustments easily and quickly.

Concerning the construction system for post-industrial houses, we will look at a concep-
tual idea that divides components based on whether they are interior or exterior, and whether they are support elements or detachable elements. Theoretically, the construction system could be any variety of manufactured parts that could be brought together in a 3D parametric design world. For this study, I am assuming a system of pre-fabricated components that can be assigned a limited, but expandable, number of material treatments. To define aesthetic character, clients engage shape grammars that render houses in various “styles”. Both the interior and exterior will have independent style algorithms that work in tandem with the parametric model. The use of shape grammars, which will be based on architectonic, contextual (site and climatic), technological, functional, aesthetic, and economic parameters, will create a versatile and dynamic system for generating new architecture.

To summarize, the post-industrial home design tool will be a product suited to the information age. It will be responsive to a wide diversity of family types, ranging from married couples with children, to groups of unrelated co-habitators. A web-based interface will be the principle means of using the tool for clients assumed to have little, if any, previous experience with the design or construction of homes. Like clothing and cars, the home will be marketed as a symbol of lifestyle and thus have the ability to be designed in various styles, ranging anywhere from abstract-constructivist to rational-classicists. Just as manufacturing industries are shifting into a client-specific customization market, so too should the house. The automobile industry of the machine age proved to be an impossible act for the home to follow. However, the automobile industry of today represents a much different model of both production and design; one that is based on increased consumer freedom and choice rather than simply “mass-production”. The shift is best described as a move from conceiving objects based solely on functionality, to an emphasis on style, image, lifestyle, and quality.

Ultimately, if the post-industrial home is to succeed, it will need to take full advantage of

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1 The principle for the construction system has been informed, although not explicitly, by the work of N.J. Habrakken, who is discussed in greater detail in the following sections.
custom pre-fabrication. The ability to ship prefabricated building components to building sites for easy erection by unskilled labor will radically change how homes are built and lived in. This proposal calls for homes with built-in adaptability and flexibility that would allow transformations to occur over time and from homeowner to homeowner. This thesis outlines a possible platform for post-industrial home design and construction. At its core, it represents a desire to see architectural services breach the housing market and provide a tool for consumers to engage, a tool that could ultimately liberate the house from the dreges of suburban monotony and control structures.

As we shall see, the information age is well suited for a positive change in the way homes are both designed and built. Socio-economic trends are redefining the role of individuals relative to product markets. Consumers are now more educated, make more money, and are more diversified than ever before, which in turn influences the very shape and appearance of technological invention. As Bell states, “Technology does not determine social change; technology provides instrumentalities and potentialities. The way that these are used involves social choices.”2 That is to say, the emerging class of educated consumers has more control over the way technology is both used and designed. We no longer operate in a system that defines work as a meaningless mechanical endeavor, but as a vehicle for creative freedom. In a post-industrial society, the home should play a significant role in the social and technological trajectories of society. It should not be conceived as an untouchable historically bound icon, but rather as a means of empowering human creativity and inventiveness.

2 Bell. The Coming of Post-Industrial Society. Page 38
POST-INDUSTRIAL TRENDS:

The principles of economy, efficiency, and social well being, guided the development of the Modern-industrial house throughout the careers of some of this century's greatest architects. Discussions of the systems used and invented by architects, and in some cases industry itself, have painted a picture of the process by which new conceptions of architecture were operating and evolving. Many of the intentions of modern architecture persist; however, a new techno-social atmosphere has emerged. Sensitivity to new materials, social patterns, and technologies were fundamental to the modernist approach and will be adopted, however it is to this new context of computational connectivity and status culture that the post-industrial house must respond.

A post-industrial dwelling will have many of the characteristics of an industrialized system. Prefabricated components will be manufactured according to material, cost, labor, and machine technology. Industrial production, which is based on the economy of mass-production, in which machines rapidly and repetitively perform an operation ad infinitum, will be replaced by mass-customized production and just-in-time production. The principle of flexibility, while not inherent in the definition of an industrialized system, should be a primary concern when creating a system that asserts itself as post-industrial. The need for flexibility within an industrialized system was recognized early in the history of the mass-produced house; however, the actual implementation of such a principle has yet to truly emerge. As early as 1910, Walter Gropius had formulated a theory of mass-produced housing that sought to merge individual needs and desires with mass-produced commodity. In a proposal presented to the AEG, Gropius stated, "It is by provision of interchangeable parts that the company can meet the public's desire for individuality and offer the client the pleasure of personal choice and initiative without jettisoning unity." Gropius, characteristically optimistic, was to never see his theories realized. The pattern becomes all too familiar the more one digs through the history of industrial

1 Quoted in Herbert, The Dream of the Factory Made House. Page 34
houses. Nonetheless, the implications of a flexible architecture are still worth pursuing, and, as we will attempt to demonstrate, more viable now than ever before.

The persistent inability of the industrial-modern home to situate itself effectively in the housing market is a puzzling and revealing state of affairs. Puzzling in that most other industries strive for continual optimization and refinement, while the housing industry has remained relatively sterile. The traditional stick frame has endured, and while it has come to rely on manufactured wood products, the home building industry has not seen a dramatic shift into alternative methods of construction. Today, mention of a factory produced home conjures images of doublewide trailer parks and low-income housing projects. What is revealed is that for a new type of construction or style to take hold, it will have to be more efficient than existing models from a performance standpoint, and even more importantly, prove to be agile in the fluctuating housing market. For a new style to emerge, the homes must be able to be sold and resold. They must offer the consumer a readily apparent value in terms of aesthetics, status, performance and economic return.

The Mass-production of a house differs from using mass-produced materials to construct a house. This distinction has created the most obvious rift between houses produced by architects and those produced by manufacturing companies. It creates an aesthetic and formal discrepancy that, more often than not, leaves the manufactured home looking very unappealing, and the home made of manufactured materials more desirable. It is for these reasons that the manufactured home is rarely showcased as a

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2 The factory-made modular house is designed to minimum standards of habitation and make no claim at being significant works of architecture. Generally speaking, the process of building modular homes is not automated or sophisticated. In Japan, more attempts have been made to create aesthetically pleasing, middle class solutions using factory assembly and automated production.
2.1.1
Clear indications of a post-industrial society: manufacturing jobs have remained constant, while professional and service industries continue to grow.

Sweeping changes in the social fabric, labor market, and computation have been steadily gaining momentum, causing many industries to rethink their approach to manufacturing. These changes will invariably make their way into the home, and if understood properly, begin to radically improve the methods and processes by which homes are designed and built. Only now, in an era of mass-customization, interconnected industries, and powerful computational tools, can we begin to reconsider the mythical industrial-modern home as a realistic alternative.

Demographic Shifts

More complex family structures and lifestyles are changing the expectations and requirement for living. The suburban model, an extension of post-war value engineering, is no longer an adequate reflection of current housing needs. People are getting married later, having fewer children, and splitting up more frequently. A large population of retiring baby-boomers will be entering retirement in the next ten years, creating an influx of demands and putting pressure on the market to create new homes. Diverse living situations demand diverse solutions. The presence of the computer is also changing the way we use the home, ranging from independent work scenarios, to casual ‘shopping’. As the networked computer continues to proliferate the middle-class, more individuals will continue to work from home, more services will be directed directly into the home, and consequently, more transaction will be handled from the home.
We are bombarded daily by stories about the Information Age. We are told that knowledge, not productive capacity, will be the key to a prosperous future. Does that mean manufacturing is dead? No, only that the market is changing from a labor force to a service and intellectual force. The United States had 18.60 million manufacturing jobs in October 1997. The only sectors that were larger were the services (35.93 million) and retail trade (22.25 million). Manufacturing remains unchallenged as the best source of income for Americans who don’t have college degrees, however the number of people with college degrees has been rising steadily, from 24 percent in 1960, to 84 percent in 1998. This fact, coupled with the rising degree to which computers are used to automate production, has created a clear break in culture from an industrial to a post-industrial economy. A new class structure has arisen that is a far cry from a Marxist model where the working-class proletariat is in a perpetual struggle with the bourgeois. The working class is no longer an uneducated mass of manual laborers, but an educated class of managers, administrators, engineers, computer scientists, health professionals teachers, lawyers and the like. The increase in education is reflected in occupational cross section of the United States.

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4 United States Census Bureau. Ibid.
As the occupation chart summarizes, the United States is not an agrarian society by any standard, and the production jobs only account for 25% of the workforce. As the United States continues to move in the direction of high-tech industry and incorporating computing into every aspect of business, the number of manufacturing jobs will continue to decline. General social stability, entrepreneurial ventures, and quality education systems combined with the shifting emphasis on intellectual capacity, have all played a role in creating a post-industrial society.

Greater social mobility and increased standards of living go hand in hand with post-industrialization. It is a remarkable fact that in 1940 only half the homes built in the United States had full plumbing. Today, that percentage is well below 1%. On average, homes have been steadily increasing in size, while the size of families has been steadily decreasing. The average size of a family is now 3.18 members, down from 3.62 in 1960. By 2010, that number is expected to be 2.53. The average number of people living together, not married was 2.83. As families have diversified and shrunk we see that people can now afford more space, more goods, more luxuries, and more education.

2.1.3
There are currently as many single person households as there are married households, yet the single family house persists as the dominant residential building type.

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The types of families have changed dramatically over the years, and this change will need to be addressed in new housing developments. The most dramatic figure is in the number of single person households\(^7\), which rose from 8 percent in 1940 to over 25% in 1990. In 1998, there were 70.9 million family and 31.6 million nonfamily households—69.1 and 30.9 percent of U.S. households.\(^8\) 27.3 percent of family households were single parent households (up from 12.8% in 1970), or 20 percent of the total. In other words, roughly 50 percent of U.S. households are non-traditional family organizations. Of the families with children, 49 percent had children under the age of 18 living at home, and 14.4 percent had children over the age of 18 living at home. These facts point clearly to the disintegration of the two-parent family with one or more children. There is no longer a standard, predominant household make-up, and yet the detached suburban home that has come to symbolize the American family dream home is still the most widely constructed type.

The number of people working 35+ hours a week from home has reached a staggering 30 percent. This fact alone warrants a reconsideration of house organization and usage. The increased ability to work at home has been augmented and made possible by the computer and network connectivity. 49.2 percent of people between the ages of 35-54 now have Internet access. For ages 18-34 that percentage is 39.3, and for those 55+ the percentage is 12.8. These are phenomenal numbers considering the Internet is less than a decade old. The numbers are expected to grow, as ubiquitous computing becomes a standard means of communicating, working, and gathering information.\(^9\)

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\(^7\) Household - A household includes all people who occupy a housing unit. A household consists of a single family, one person living alone, two or more families living together, or any other group of related or unrelated people who share living arrangements.


As the demographics suggest, changing socio-economic trends have come to bear, and we have reached a critical moment in the development of American homes and neighborhoods. The fabled 1950’s American dream family is not a reality, nor is expected to become one. And yet, developers continue to build communities based on the Levittown model where it was expected that women would stay home and watch the kids, while men commuted to work. Today, most families are two income families, and that means more commuters making long trips to isolated office parks and urban centers, leaving their neighborhoods to become “bedroom communities”. This pattern, which is no longer practical or desirable, is in need of serious reconsideration. If the development of more aggregated and ambiguous communities is allowed to happen, then suburban doctrines of zoning and density can be broken down, and ultimately prevent sprawl from further deteriorating peripheral landscapes. As working, living, and entertaining blur together, so will the neighborhood fabric.

This thesis supports the idea of multivalent family structures influencing the shape and appearance of individual houses, should, in turn, influence the community fabric. Redefinitions of workplace, living space, and community space are becoming increasingly necessary as post-industrial culture continues to surge forward. While we will not venture into the scale of designing neighborhoods and cites in this thesis, it is important to keep in mind that the home is not an isolated object, but part of a larger organic system of interrelationships. The homes designed with the proposed tools would ideally be connected to a larger urban planning scheme that addresses issues of transportations, scale, zoning, community space, and density. New urbanist approaches to planning would be worth exploring in subsequent research regarding post-industrial land use and cities, both of which are in need of a dramatic overhaul.

Concurrent with the shifting definition of family are media induced reflections of changing attitudes and lifestyles. Pop cultural media formats such as TV, film, and music, which in turn influence the development of new products, promote stylistic images that become instantly commodified. The form of the house is often depicted in such formats, in which...
case the architecture is toned down and repressed, while attitude, humor, taste, and relationships are pulled into focus. Why has the architecture of situation comedy not changed? How is it that the television genre can change dramatically over the course of a decade, yet homes still look the same? Without doubt, this has only made the task of liberating the home more difficult. Never the less, the consumer market needs to be taken full advantage of in order for post-industrial homes to become desirable and viable status icons. Perhaps a media giant will one day promote new types of homes for a new generation, creating a mad craze for inventive and utterly hip homes.

Changing Trends in the Market

The middle class is no longer struggling to make ends meet; they have in-fact entered into a luxury market, and are re-defining new standards of living and criteria for social status. We have witnessed a shift from the mass-production of generic products to the mass-production individuated products. In other words, specialized services and products are on the rise. The United States consumer has become obsessed with commodity and the ability to define individual modes of expression. Our society has become one defined by status, rather than class. As Daniel Bell writes, "In sociological terms, changes in lifestyle are associated with a move from class to status. A class-based society is one in which the central concerns of individuals are economic, e.g. getting a job, having enough to eat, finding a home, etc. The status society is one where the social approval of others, or the adoption of different styles of dress or costume, become the signature of a declared individualism." ¹⁰

According to Bell, the market of customization is an indication of a social change in economic liberty, where individuals are freer to determine their own stylistic destinies.

¹⁰ Bell. The Coming of Post-Industrial Society. Forward to the 1999 edition, Page lxxv
This is seen readily in the abundant types of product currently available in an increasing consumer-oriented market.

A good example of products becoming more user-specific, and less generic, is the cellular phone. The technology of telecommunication is now routed directly to individuals, wherever they happen to be. No longer do people go to a phone, the phone has come directly to the individual. Not only that, but every cellular phone has built in menus for customizable databases of numbers, memos, and even Internet news broadcasts. The latest trend toward virtual newspapers is another telling example. Traditionally, the newspaper has always been delivered directly to customers, however the news is generic and non-specific relative to the reader. Now, with personalized profiles, one can access news from the web that is pre-filtered according to preferences in news type, source, and importance. Personalization filters, or profiles, are becoming standard means of accessing information and receiving product. The design of a home should be no different.

Internet start up companies like Amazon.com has gone to great lengths to capitalize on this methodology by providing information that is tailored to specific clients. Based on previous book or music selections, the site returns other material that you would likely interest the consumer. In effect, the process has streamlined browsing and searching and begins to break down the limitations of categorically organizing material. In a traditional bookstore all material is organized by genre, and consequently reduces the serendipitous location of related material in other genres. Of course, Amazon.com is but one example of hundreds of sites that offer customizable user preferences. This trend will continue to expand as the e-commerce market place grows, resulting in sophisticated search engines that bring products to consumers.

Trends in product design, service infrastructure, information collection, and distribution are changing the way that consumers experience product, make purchases, and interact with industry. A recent example of a service industry being redefined is movie rental. Now it is possible to search through movie selections on-line from the comforts of home,
see what is available, and have a video, food, and drinks delivered to your door within an hour of placing an order (re: kozmo.com). Even more intriguing is the strategic placement of drop-off locations: at local cafes, grocery stores, and retail shops. The experience and process of renting a video is fundamentally altered. Rather than driving to the strip mall and making an anonymous drop-off through a slot, you now take a walk to a nearby café, perhaps get a cup of coffee, establish a rapport with the clientele, etc., and return the movie. The model reinforces the trend toward consumer-oriented design and service. The notion that the computer will isolate individuals and destroy public space seems ludicrous to me. I imagine quite the opposite happening, and as a result, the development of fewer innocuous strip malls.

The house should participate in the information revolution the same way that many other businesses are operating within the framework of information markets. The housing market can be revolutionized via an understanding of distribution, organization, market, and industry, merged with a desire to see homes become more user-specific and demographically calibrated. Establishing criteria for the post-industrial house is a multi-faceted problem, but is fundamentally grounded in a concern for choice and free will.

Emerging Computational Tools

Throughout history, people have used various devices to perform mathematical operations. From fingers to computers, from the abacus to the graphing calculator, these tools have made computing easier, complicated tasks simpler, replaced manual tasks, and contributed to further developments and discoveries not only in mathematics but also countless other areas as well.

The history of the computer is well documented and follows a logical trajectory. Machines have gone from huge and manually operated, to microscopic and totally independent. In 1960, the programming language ALGOL (ALGOrithmic Language) was created. The computer Mouse and “windows” were invented in 1964. The programming language BASIC (Beginner’s All-purpose Symbolic Instruction Code) was also created in
1964. The first computers using integrated circuits were built in 1967, and in 1968 The Intel Corporation was started. By 1969, work had begun on ARPAnet, a precursor of the Internet, which fundamentally changed the manner in which computers could be used. Since then, memory, processor speed, hardware and software have grown exponentially. Now, virtually every computer is connected to a vast array of interconnected computers, bringing improvement in every area of knowledge.

Computer aided design (CAD) and computer aided manufacturing (CAM) have developed in full stride with computers. Direct linkage between drawings and machines saves time and maintains consistency in projects. Parametric modeling of buildings is finally hitting the market with programs from industry leaders such as Microstation, with TriFroma, and Microstation J. These programs operate using an object-oriented language to maintain cohesive rules and relationships of parts to the whole. Every parameter of any given object is known and is in direct relation to other objects. Users design completely in 3D, from which plans, sections, details or material selections are extracted. These systems often include large libraries of parametric building components, such as doors, windows, and structural parts, and offer the ability to endlessly add components to the library.

Parametric computer programs are essentially mathematical objects. In particular, individual computer programs are instances of sets of values in discretely parameterized mathematical models of the physical world. The software is an emulation of natural laws of cohesion and action/reaction sequences. As one parameter is changed (dimensions, materials, coordinates), the entire model is updated and reflective of such changes. All objects are arranged by type, and are thus intuitively organized.

Modeling in 3D has the advantage of allowing designers to more fully conceptualize design problems and solutions. In a web-based application, photo-realistic 3D rendering will be essential for clients to make decisions and understand the ramifications of such decisions. Using parametric technology, rapid adjustments can be performed without difficulty by implementing preset object-oriented methods. The modeling environment will be organized by a set of logical rules that define the limits of possible adjustments.
Thus, the system would have a built in knowledge about structural limitations, window/wall relationships, area and volume requirements, and user-defined spatial rules.

**Implications and Directions**

Demographic trends show that the family structure in the United States is continuing to fragment and diversify, in turn placing new demands on the housing market. The middle class consumer is no longer an uneducated tool for production, but an educated, status oriented professional. As more people continue to jack into cyberspace to buy products, search for information, advertise, or otherwise publicize, the market for on-line services will expand enormously. The current state of solid modeling software is at last becoming fully parametric and can now be linked directly to manufacturing processes and inventory databases. If we combine these three forces, diverse families, the educated professional middle class, and web-enhanced CAD systems, we can imagine a web-based, parametric home design tool that is linked to industry, affordable to middle class America, and encourages the development of new construction techniques.

Imagine clients entering a web site, locating a real estate development, and defining design variables that ultimately generate unique 3D house models. Each model could be purchased as a system, which would in turn be pre-fabricated then shipped to a local contractor, and assembled in a matter of days. At the back-end, modeling software would integrate mathematical grammars to maintain organization coherency, tying the web page model directly into manufacturing facilities and distribution chains. On-site labor would be reduced, mistakes avoided, and information kept tight as a button.

By dramatically reducing the need for on-site construction work and finishing, homes can be built to higher standards of material quality and durability while remaining economically competitive. How we get to this vision is the subject of the next two sections. Issues of user input, shape grammars, transformations, and adaptable domestic architecture are all addressed, with a case study of post-industrial home design.
ADAPTABILITY AND FLEXIBILITY:

NJ Habrakken, who worked extensively on the concept of supports and detachable units in the 1970’s, sought to define criteria for adaptable mass housing. His premise was that houses need to be constructed such that any number of potential residents could move into a building and be allowed to make personalized changes based on their needs and desires. Elements that allow for user manipulation and inflection are defined as "detachable units", while the structure or shell into which such units are allowed to change is considered a "support". On the subject of adaptability and supports he writes, "The support is designed in such a way as to provide potential for varying the floor plans over time, but the support must be capable of accommodating dwellings which meet the standards normally accepted for housing in any particular society. Adaptability and variety must give those who finally occupy the support building maximum choice without requiring technical expertise or excessive effort on the part of the resident."  

Two key concepts are raised: supports should allow for easy transfiguration, and they should satisfy, at the very least, minimum standards of living relative to the society into which they are situated. The support itself does not have to change over time, but it must support changes over time. In other words, it must be conceived with the notion of detachable units from the onset. On detachable units, he continues, "A set of detachable units contains elements which are then built into the support to make the dwelling...detachable units should be adaptable, capable of being used in many different combinations, in different support structures".

As is evident, the concept of supports and detachable units clearly delineates two princi-
pal components for home construction.

In order to facilitate maximum adaptability and flexibility in the home, all post-industrial homes would be designed using a similar conceptual framework to the one laid out by Habrakken. Each house will consist of a structural envelope within which detachable interior modules are organized to create rooms, storage, partitions, cabinets, and service ducts. Every design generated will demonstrate the ability of the home to change over varying lengths of time. All interior walls are both adaptable and flexible; where adaptable implies the ability to change space as fundamental living circumstances change, and flexible implies the ability of objects to be moved or changed on demand. The arrival of a new baby may require a re-partitioning of space to create a new room. Such changes would require a system be adaptable. An example of flexible use would be converting a workspace into an entertainment space by rotating a wall, or sliding a module out of the way.

The importance of flexible and adaptable architecture cannot be overstated, especially when considering the relative stasis of current housing solutions. In the typical developer's house, interior walls are not designed for easy manipulation or demolition, nor are homes easy to reconfigure. Renovations are expensive and time-consuming activities that are more burdensome than convenient. Structurally, houses often rely on interior walls to support roof trusses, which only complicate issues of alteration. In making the distinction between “support” and “detachable unit”, we are radically departing from conventional home building practices.

To retouch some issues brought up in the first part of the thesis, many of the modernist architects proposed open architectural systems that created the possibility for free plans and facades, but rarely sought solutions that specifically incorporated detachable or kinetic interior components. The work by Le Corbusier and Walter Gropius points toward such ideas, however, they never developed the concept to any significant end. The
modernists recognized the inherent freedom of planning by taking advantage of new structural systems, and worked primarily with non-structural screening elements such as curtains, thin walls, and curving surfaces. In the modernist vocabulary, interior, non-structural components were meant to contrast the structural rigidity of steel and concrete, and thus assumed light, transparent and ephemeral qualities. Johnson and Hitchcock:

"In contrast to the completely enclosed rooms of the past, they stress unity of the whole volume inside a building. The independence of dividing screens and their variation in size and creates contrast within the regularity of the isolated supports. The flow of function and the relation of one function to another can be clearly expressed. The different screens serving different purposes may well be of different materials provided always their thinness and freedom from structural duty is stresses." 4

Essentially, the post-industrial house will incorporate concepts of open architecture as advocated by Modernists, but extend the idea by developing adaptable and flexible systems of interior components. In contrast to the International Style favoring of thin interior partitions, this proposal calls for thick units that nonetheless allow for an open architecture. The extension of modern principles is also made in regards to the type of production used to create such architecture, where the use of industrial processes is considered not only adequate, but also essential to the project of modern as well as post-industrial architecture. The primary difference between industrial modes of production and post-industrial modes will be the degree to which parts and aesthetics can be specified by consumers, in other words, the ability to customize products without driving costs up or complicating fabrication by any significant degree. A possible solution is outlined in the following section that calls for a new construction methodology that supports adaptable and flexible domestic architecture.

4 Hitchcock and Johnson. *The International Style*. Page 87
Adaptable Component-Based Architectonics

Each house will be constructed out of a proposed industrially manufactured component system of exterior panels and interior partition modules. The module is based on 2’ x 2’ grid, such that interior units are either 4’ or 2’ in breadth. Exterior panels are generically 6” thick and constitute the thermal envelope and structural system of houses. The exterior panels create the envelope of the house and include structural and non-structural types of construction. The interior modules serve as primary wall partitions, closets, heating and cooling ducts, electrical supply chases, and cabinetry.

Using a parametric modeling platform, each panel could be stored directly in virtual model, and then sent to a manufacturing facility for construction. Similarly, clients could be given real-time cost estimates, and the ability to cross reference prices and availability of specific manufactured products. Depending on the design intentions of the client, panels could be made of varying dimensions (within the limits of the structural system). Thus, structural panels could range anywhere from a 6”x6” dimension up the width of a flatbed truck. The limits of the system are experimented with in the design transformation sequence. The more industries that participate in modeling CAD compatible objects, the greater variety of option will be made available for consumers to select from.

As mentioned, interior and exterior cladding can be rendered in any number of materials and finishes. Manufactures would spec their product to be used in the visualization tool, allowing clients to swap veneers and compare aesthetics as well as prices. Once the house is “finished”, and all product selections have been made, the information would go directly to both the product manufacture and the panel construction contractor. This approach would offer consumers more leverage and buying power in the market, which would in turn stimulate new levels of competition, and ultimately provide better products for building.

The actual construction of the panels has not been addressed in this research; such a task will likely fall on the shoulders of an engineer later down the road. From an economic
2.2.4 Interior moduals will replace conventional stick framed walls. Each unit is detachable, replaceable and upgradable. Closets, dressers, counters, partitions, and storage are all handled by the interior units. Technological innovation in the field of CAD/CAM cabinet milling would be taken advantage of in an effort to make the units affordable, customizable and pre-fabricated.

and precision standpoint, an engineered product will likely be used as the primary structural material, be it lumber, steel, fiber-composite, or a lightweight concrete. One can imagine different materials becoming a regional preference, and even a stylistic motivator that could re-create new regional aesthetics. Either way, the use of dimensionally unstable framing lumber, with its inaccuracies, low tolerances, and instability, will not be desirable or efficient.

More dynamic than the structure and enclosure system will be a system of interchangeable, interlockable, and flexible modules that supply air, heat, and power throughout the house. These modules, which are considered “thick” elements, replace conventional notions of closets, pantries, utility rooms, bookshelves, dressers, partitions, walls, and service ducts. The modules accomplish all these functions, and are additionally able to be taken apart, removed, rotated, and reinterpreted. The interior units allow for multiple types of configuration and represent a means of making homes more adaptable, flexible and stylistically diverse.

Towards an Adaptable Domestic Architecture

Adaptability is accomplished by designing homes that can grow, shrink, adjust, or otherwise be replaced. As the needs of the client change, so does the configuration of the interior living space. This is demonstrated in the case study design by a set of diagrams showing possible transformations/adaptations over time. Manufacturers can design furnishings, claddings, and technology to fit within each module. For instance, a company like Sony could pre-manufacture entertainment consoles that fit within modular dimensions and be detailed in different styles.

Having laid the framework for the tool and the conceptual groundwork for an architectural system, we now have to test the theory with a case study example. The following section will take a hypothetical family through the various steps of the design process and arrive at a solution that demonstrates the use of a parametric shape grammar and the flexibility/adaptability of a construction methodology to create dwellings.
Example of a structural bay using window and solid type construction, with an end wall shelving assembly that is non-structural.
A NEW HOME DESIGN TOOL:

Until recently, economic constraints largely dictated how a product could be customized. With the computer and new methods of automated manufacture, the rules have changed. Customization, in the broadest sense of the word, implies a direct and user-specific relationship between the shape and appearance of an object or service, and the needs and desires of the end-user. A totally customized home implies a perfect synchronicity between the inhabitants and their home over an indefinite period of time (i.e. the home would be able to ‘grow’ and ‘shrink’ as needs or family structure changed). Such a home would have varying scales of changeability ranging from daily adjustments to twenty-five year generational changes. It will also be customizable in the pre-construction, design-development phase. Before long, the customized house will become a hot market item for a large range of consumers. This section explores a possible framework for creating custom architecture using client preferences, shape grammars, design transformation rules, and a construction system that supports adaptation and flexible usage.

As mentioned in the previous chapter, customization can and should be made available to a larger market. How this can happen is a complex and multi-faceted problem that involves a whole gamut of manufacturers, builders, homeowners, and lending institutions. Two principal systems that could potentially bridge the gap between all the various players are being proposed: (1) a web-based design tool that consolidates information about specific users, (i.e. aesthetic sensibilities, work habits, activities in the home, etc.); and (2) a method of generating possible solutions (based on that information) using an architectonic system of customizable interior and exterior components.

Both solutions, which work in tandem, connect consumers directly to a world of manufactured products. Once products (exterior cladding, kitchen cabinets, wall storage units, etc.) are selected for a house, information would then sent directly to manufacturing facilities and a distribution chain. Parts would be assembled by a third party manu-
facture responsible for the construction of individual components, which would then be distributed to job sites for easy installation by unskilled to moderately skilled labor. Because homes created with the tool adhere to a system of pre-established grammatical rules, structural integrity, spatial continuity, and overall adaptability would be maintained from the user interface down to the erection of a house. In other words, the program must ensure that there are no “loose ends” or missing details.

A tool for the design of post-industrial architecture will rely heavily on the power of computation to generate a wide variety of solution types by following parametric shape grammars. A shape grammar provides a mechanism for creating rules based on variables and sets of relationships between objects. The grammars proposed are based on architectonic, contextual (site and climatic), technological, functional, aesthetic, and economic parameters. Specification of needs and desires in a matrix of parameters will create a unique user “profile” able to generate design rules. The rules will inherently produce numerous possible outcomes, perhaps thousands, all of which can be adjusted at any point in the design process. The premise is that, by structuring the grammatical relationship between the properties associated with the house and the needs/desires of users, a program can generate balanced solutions that take into consideration a wide range of clearly defined variables. Functional needs, augmented by compositional preferences, would be organized as spatial 3-D shapes that share boundaries with other shapes to create architectural massing models. Once a massing composition is defined, geometric complexity, aesthetic selections of material, and style would be mapped onto the model for further exploration. The following sections outline a framework for the user interface, client information gathering, massing grammars, trans-

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1 Stiny. *Introduction to Shape and Shape Grammar*. Pages 409-462

2 Krishnamurti. “Toward a Shape Editor: the Implementations of a Shape Generation System”. Pages 391-403
formation grammars, the provision of adaptability and flexibility in design using the proposed construction methodology.

Design Interface

The design tool will act as an interface between clients and user specific solutions. Collecting useful information from the client will occur at the front end of the tool and be instrumental in the creation of design rules that influence backend operations. The interface consists of three primary components: user profile, transformation rules, and visualization window. The profile holds vital information relevant to the client such as style, building context, spatial preferences, age, budget, habits, hobbies, and activities. Transformation rules, which add or subtract complexity to the model are based on the geometry of the initial spatial relationships generated by client information input.

The transformations are a set of variables that the client can adjust in order to explore various architectural options such as abstract geometry, symmetry, and material selection. The visualization field displays renderings of plan, perspectives, and massing model. Clients will be able to save models at any point in the process as “favorites”, to which they can return and compare with other models, or change variables and output yet another variation. The process is both linear and iterative. Information collection is a linear sequence and generates primitive spatial relationships. Clients are guided through questions that are realized by a shape grammar as a 3-D massing model. The second part is an iterative design game that allows clients to transform the primitive massing and volumes into any number of possible combinations. Transformations occur as two separate operations: interior and exterior. With each transformation, evaluative feedback is provided relative to floor areas, volume, cost estimate, energy savings, and natural lighting. Individual rooms may be evaluated, or the entire model.

In the future, one can imagine interior furnishing being selected and placed in the model by building a library of manufactured products on the market. For instance, the tool could import parametric models of furniture, lighting fixtures, entertainment systems, or artworks that would then be merged with the model for visualization purposes.
scenario, the tool would provide a valuable marketing service to industry. In the future, manufacturing companies would ideally compete to get their products into the database, and even provide direct access to on-line product specifications. Individuals would be able to shop for furniture and to visualize their options while designing their house.

The user interface will consist of an information collection framework that informs subsequent options and design possibilities. The location of the site, size of family, spatial needs, and functional requirements are all addressed. Thus, when selecting a climate zone, homes will have meet specific performance criteria. Because a home specified for Minnesota will have different types of construction and mechanical needs than a house in Florida, different performance criteria will have to be built into the grammar. All designs that emerge from the process will meet specific performance guidelines regardless of any formal and aesthetic goals. Certain types of expression will thus be limited by either climatic or cultural conditions. This may seem overly restrictive, however, in the interest of creating responsible architecture certain guidelines need to be established. Of course, the end user will have control over the design options and stylistic preferences will be completely in the hands of the client.2

Once climate and site information has been obtained, the user moves through a question/answer dialogue in order to best arrive at the types of activities that will need
to be supported in the house. Spatial rules will be created based on the client input. Thus, a client may want the master bedroom removed from their children’s bedrooms, and their office adjacent to the kitchen. This is all facilitated by a series of mouse clicks in the interface, which has pre-set parameters built in. Another client may have no need for an office, but prefers a study or library. These types of activities would be gathered in the profile and used to generate house schemes.

All bio-information is recorded on the web site, creating a client-specific profile of needs and desires that exist on a private database. The challenge, of course, is to ask the right questions such that a solution can be generated that is in tune with the client’s personal sensibilities. e.g. a fun-loving high energy sport fanatic, who loves to watch football every Sunday, should get a design that not only accommodates those needs but goes so far as to accentuate the experience. A client should be able to establish preferences about the types of activities occurring in any given space. Thus, a conventional living room should be able to be converted into a huge multi-media entertainment extravaganza for special events.

2 Of course, for people living in Southern California, there is no limit to whimsy, and the author would suggest that the breezy, sun-filled climate was largely responsible for the creative frenzy that surrounded the Case Study Program.
Having established the types of activities and relative relationships between activities, a shape grammar is used to construct various three-dimensional models. From these models, the client would then be allowed to explore the architectonic values of specific functional zones like sleeping, leisure, entertainment, cooking, storage, etc. Each room type will be examined in 3-D model form with a set of tools that allow for rapid visualization of various parameters. The user will be able to 'slide' the design through these parameters and experiment with different configurations.

As mentioned previously, each operation creates a variation, which can in turn be re-operated on. Likewise, at any point in the process, a user could return to their profile and make changes, which would in turn create new spatial relationships. Ideally, each type of transformation would have a scale of possibility that ranges from the totally radical to the hyper-standard. The tool should encourage playfulness in the design process, allowing clients to specify unconventional combinations of characteristics as a way of defining their own style of home.
Client Information Collection

Getting relevant data from clients will be an essential part of the tool, and represents the first part of the design process. The interface for this should be clear and not an endless series of questions that gets the client lost. The variable should be clear and tunable. Selecting the site should be as simple as using a service like Mapquest.com, where an address is typed in and all relevant data concerning the site is logged into the program as building constraints. Likewise, choosing options should be intuitive, streamlined, and interesting. Options should be easy to understand and have an appropriate graphic representation in the visualization field.

In order to create a building envelope, we will need to have information about the site, local climate, and building codes. Then, we want to know what types of activity people do in the home and when they do them. If we know that a client only uses an office in the evenings, then perhaps we can imagine a more efficient use of space that allows the office to be used in a different manner during the daytime. It could, for instance, be a playroom during the afternoons, and then convert to office-mode later in the evening. Charting this information will establish which spaces can be multifunctional and need to be designed as flexible spaces. This information will inform decisions about the type of space best suited to their needs, what rooms should be connected or unconnected, what should be public and private, and which rooms should be multi-functional. Based on the preferences and priorities of individual clients, a model is abstracted that represents primitive spatial relationships between rooms and their associated activities. Clients will specify desired sizes of rooms, their relationship to other spaces and activities, connections to outdoor space, and whether spaces need to be isolated from other spaces, i.e. an office may need to be isolated from a recreation space.

Initially, clients specify the types of rooms they need to facilitate their activities. These are broken down into the typological categories of bedrooms, kitchen, dinning, recreation, studio, office, bathroom, and garage. Each room type can be designated as open/closed, public/private, upstairs/downstairs, and connected/disconnected, connected to
outdoor public or private space. Each room is also given plan (x,y coordinates) and volume (y coordinate) characteristics. For the plan the choices are small, medium, large and extra-large. For room volume, low ceiling, average ceiling or tall ceiling can be specified. A visualization of the type of space is provided that lists the square footage, volume, estimated cost, and most importantly, places prototypical furniture elements in the model. Every room has two buffer zones: one for the 2'-0" module wall dimension, and the other for an 8" envelope shell.

Clients begin by specifying the number of types of rooms desired, if any at all. Activities are marked, as well as ceiling height, what other rooms should be connected, and if a bathroom should be included. Each room is then shown in relation to other room types that have been selected based on whether the client wants certain connections. For instance, a recreation space may be specified as connected to an office. Several grammars are generated that show different spatial organizations for the two room types as they relate to one another. The grammars generate a number of possible house configurations to choose from, ranging from a compact box to a sprawling pinwheel. All plans are organized on a two foot by two foot planning grid that orders the structural system as well as interior space.

When a client is a family of two or more people, as is often the case, conflicts are bound to surface. For example, a husband may not feel strongly about having a formal dining room, while his spouse feels quite the opposite. Or two unrelated professionals may argue over who gets an office on the ground floor, and how the "recreation" space is used. In instances of extreme disparity, each person could opt to generate their own grammar, which could then be compared with the other household member's designs. Likewise, the program could generate a "best fit" hybrid scenario that attempts to satisfy as many

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3 Site restraint will of course dictate the appropriateness of designs and reject them if they do not fit within the design envelope.
of the client needs as possible. The individual household members would then have to negotiate options and look for reasonable trade-offs. For example, they could be asked to rank options on a scale of 1-10, in order to establish a hierarchy of preferences.

Spatial relationships are ordered according to rules. The rules are informed by parameters set by users, and constitute the primary mechanism for organizing program elements. The size of the site will largely determine if a house is to have a compact or sprawling plan. However, whenever possible, the grammar will return both compact and sprawling plans. If rooms cannot fit on the site, they are moved to the second floor and possibly third floor. Each room can be rotated using simple symmetry operations, allowing more varied designs to emerge. To keep the designs relatively simple, only ninety-degree rotations are used in the initial grammar. In subsequent stages of the design process, more complex geometric rules can be applied that add spatial complexity and asymmetrical organization to houses.

The location of load-bearing shell elements and interior module units are built into the grammar such that exterior walls are defined as shell, and interior walls are defined as furniture modules. A ninety-degree rotation of a room type will thus not rotate the architectonic elements, but stretch and shrink each element relative to the new spatial relationship created by the rotation. Every room has at least one entire module wall dedicated to storage. Where adjacent rooms share a module dimension, the wall will be divided equally between each room, provided each room already has at least one dedicated module wall.

2.3.6
The rooms depicted show a relationship between a home office and a bedroom or a small bedroom and a larger bedroom. The same type of rules apply to each of the other rooms and will be demonstrated in full with the cases study example in section 5.0.
The Future: Design Transformations

Two primary transformation variables, plan and massing composition, and interior module composition, constitute a fine-tuning mechanism of the tool that is not present to any degree in the current middle-income U.S. housing market. The tool offers architectural services that would otherwise be reserved for wealthy clients who can afford full architectural services. In a suburban development, prospective homeowners have a limited number of models from which to choose, and the homes from which they do have to choose are all built to a generic standard. Materials, composition, site orientation, and user input are all excluded from the equation when a developer begins the process of building houses. This model seeks to change the rules of the game. In the future, one can imagine developers offering access to the design tool as a selling point. If backed by a developer, diversity and creative expression could be promoted without causing alarm in the eyes of lending institutions. A key feature of the homes is a built-in adaptability and flexibility that will allow houses to change over time to accommodate different family profiles. From an economic standpoint, this makes a lot of sense given that a home is a substantial economic investment. From a resale standpoint, if homes can be proven to be adaptable to many types of families, it stands a good chance of being sold on the market. The next section examines flexibility and adaptability more explicitly.

Transformations can occur by using tools that adjust formal massing, exterior cladding, interior finish, window treatment, natural lighting, and artificial lighting. Generally, these categories encompass the architectural principles of composition, material, and light. Each transformation is tied directly to the parametric model, which allows the model to maintain consistency at all times. No change can occur independently of the model or any other transformations.

Each transformation set would allow clients to “slide” the design between various descriptive alternatives. The composition transformations allow the client to select between several variables or “axes”: symmetrical/asymmetrical, concrete/abstract geometry, aesthetic character, and open/closed. A middle territory can be explored that has aspects
of both alternatives, and it is this area that will have the most promise for generating complex and interesting architecture. Each description is an abstract concept that can be manifest in form and space as the extreme positions, or as ‘both-and’ compositions. For materials, selections are made according to pre-assembled style palettes ranging anywhere from Scandinavian to Industrial design. In the future, the range of material selection could grow immensely and include “designer” options, as well as randomized search patterns that return unusual combinations of materials. The lighting transformation permits the client to change the amount of natural and artificial light. Window patterns, which correspond to material palette selections, are designated as well as types and styles of artificial lighting. As a user slides from one of two extremes, graphic examples and diagrams will appear, providing an index of images through which associations can be drawn. Each transformation operates on the current state of the spatial model, and allows the user to explore varying scales of complexity, contradiction, and style. For instance, a user can choose a symmetrical composition that is open, a “Martha Stewart” material palette, and large expanses of glazing for maximum daylight penetration.

The middle ground between two oppositions, or the inclusion of both, is where complexity arises in the form of ambiguous “both-and” compositions. Or as Venturi has stated, “It can include elements that are both good and awkward, big and little, open and closed, continuous and articulated, round and square, structural and spatial.” I am aligning with Venturi on this issue for several reasons regarding domestic architecture: For one, it is an expression of human freedom; ambiguous architecture allows the mind to traverse many different terrains. Secondly, “both-and”, or “multivalent”, has become a guiding principle in the design of the information gathering interface and the domestic module architecture that is described in the next section. The principle is that any given space can be modulated or adapted to suit a variety of different activities and user needs. Thus,

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“living rooms” can also be “offices”, a “playrooms”, or “home theaters”. Third, complex architecture is more interesting, more in tune with our own experience of the post-industrial world, and more dynamic than simplified, overly ordered and often sterile architecture. It is critical that the architectural design tool allows diverse and complex architectural solutions. We do not want to lapse into the emptiness of suburban mass-production, nor do we want to create semantically deprived deconstructions. Of course, variations of each of these opposites will be available, and ultimately reversible.

Each transformation is best illustrated by example. Both poles as well as multivalent forms will be described briefly. In the user interface, examples would be provided to better understand what each decision entails. Mathematical grammars and the parametric 3-D model will handle modifications and return variations.

**Interior Module Wall Transformations**

Clients will be able to assign material palettes to their interior design based on a list of preset aesthetic orientations. The range of possibilities is only limited by the degree to which manufactures are willing to introduce new materials into their building vocabulary. While initial stylistic preferences will be limited, clients could conceivably specify different materials for every wall, room, or detail. A list of options would be made available that would include, among others, Modern, Scandinavian, Classical, Industrial, Country living, Natural, Mediterranean, Recycled, Martha Stewart, Plastic, Southwest, Techno, and Prairie. A breakdown of styles would alleviate the burden of finding the right paint, decor, or even furniture. As the program becomes more robust, industry manufacturers will be invited to showcase their products in homes and to be included in the database of parametric modeling components. With each selection it will be important for clients to compare prices, life-cycle costs, guarantees, and whether or not materials can be recycled. The life-cycle cost estimates will be the most crucial information, empowering clients to make more informed decisions about the types of products they select based on the cost of replacement, maintenance and the like.
Light is as important to good architecture as any other variable, and constitutes an equally important role in the design sequence. The arrangement of windows will be determined in the proceeding steps; however, a client could start by specifying lighting desires if they wanted. On this axis, individual rooms are examined and assessed using simple ray trace operations to render the space at different times of day throughout the year. Light filters specified in this segment include blinds, shutters, auto-diffusing glass, electro-chromatic glazing, photovoltaic arrays, and conventional blinds.

**Plan and Massing Transformations**

Three possible design transformations are briefly outlined that begin to suggest how architectural complexity could be worked into future developments of the tool. Initially, of course, the tool will generate simplified geometric plans, that could then be diversified and given more formal and aesthetic character by introducing asymmetry, openness, collision, oscillation, decentralization, and contradiction. Here, three design axis, geometry, openness, and aesthetic character, are delineated and placed in the context of various innovative home designs.

The first axis is geometry and responds to organizational as well as site derived geometric abstractions. Variation of symmetry and asymmetry are available, as well as the extension of regulating lines both into the site and within the house itself. A Palladian villa is an example of strict bilateral symmetry that is based on a reflection rule: what occurs on one side of a building is mirrored to the other across a central axis, creating a sense of equilibrium. Classical symmetry calls for both plan and elevation to be reflected across one or two principle axis. Many classic American prototype houses are of this type, specifically the saltbox, Georgian, and bungalow. Asymmetrical examples are those designs that depart from explicit reflection rules and have no dominant axis. Works by Coop Himmelblau, Asymtope, or Lebbeus are characteristic of asymmetrical design. A multivalent example would be Le Corbusier's Villa Savoye that has a highly symmetrical façade and structural grid, but an asymmetrical arrangement of rooms. Work by Mario Botta is another example.
Geometry is polarized in the tool as concrete or abstract. A concrete geometric design will have a clear and understandable narrative structure, while abstract designs are intentionally detached from content and more difficult to understand. Concrete space is more or less functionally driven, while abstract geometry is semantically ambiguous and aesthetically derived. Examples of houses that have a concrete geometric organization include the conventional developer home, and modern homes such as the Gropius house and Wright’s Prairie homes. More abstract geometries are found in Peter Eisenman’s houses from the 1970’s, or Masaharu Takasaki’s Zero Cosmology house. In the middle, lie examples such as Wright’s textile-block houses that are both formally abstract, yet clearly articulated in plan. Likewise, the work of Tadao Ando occupies a middle landscape, where formal abstractions form uncompromisingly concrete spaces. Geometric complexity is achieved by using transformation rules such as non-orthogonal rotations, skews, translations, and extensions.

The second axis concerns the degree to which spaces are either open or closed in relation to one another. Whether a space is open or closed determines the spatial feeling of a room or building. Open architecture reduces the number of walls and opens rooms to outdoors and to each other, whereas closed space compartmentalizes rooms, giving a greater sense of enclosure and containment. Closed houses include most classical prototypes, the developer house, etc. Opposite would be Johnson’s Glass House, Mies Van Der Rohe Houses, Koenig’s Case Study House #22. Wright’s Prairie houses are good example of open public space merged with closed private space. Likewise, many International style homes incorporated large spacious living spaces that had distinctly closed sleeping areas. Le Corbusier generally included double-height open volumes that were buffered by small boxed-in sleeping chambers.

With the proposed construction system, a homeowner will be able to adjust the home design post construction to satisfy any of the given variations of open/closed architecture. A totally unconnected set of rooms could be made entirely open to one another or simply connected with a door. As homeowners cycle through the house, multiple scenarios can be explored that are more responsive to individual family needs and character-
The third axis is aesthetic character, and defines an exterior cladding system. Material selection can be used to create both spectacle houses and “contextual” houses. The use of unusual or contrasting material can set homes apart from their surroundings, creating regionally detached instances of individuality. These are typically considered object houses with an obvious bent toward distinction. Their opposites are those homes that merge with their surroundings as far as possible: blending, assimilating, and disappearing into the landscape in an attempt at aesthetic unity. The Rotonda can be sighted again as an object house, as well as Ushida/Findlay’s Truss Wall house. More contextual houses can be rendered differently depending on their context, be it urban or rural. Rural examples might include bermed earth houses, Taliesen West, and Mike Reynolds’s Earthship houses. At the suburban scale, this might be a house that conforms to an existing style, or a rowhouse the merges seamlessly with existing building stock. Both-and examples would include work by Morphosis, which attempts to weave projects into existing regulating lines of force, but are still rather object-like. Neutra houses, Philip Johnson’s Glass House, and the Eames House are use industrial materials, but the use of glass and vertical column rhythm is able to mesh with the surrounding trees and matrix of foliage.

These three compositional transformation axes would combine to augment the formal massing and aesthetic quality of the house. As mentioned, program arrangement would be handled in the activity analysis that produces generic spatial rules. Transformations take the design a step further by allowing clients to experiment with changing design variables.

Concluding Remarks:

The success of new computationally driven design tool will be subject to how well client preferences are effectively mapped into actual architectural objects. In other words, a clear relationship between the user of such a tool and the final output needs to be estab-
lished that meets the spatial, organizational and aesthetic goals of any given client. The ability to specify room size, height, types of activities and explicit connections between room types are generic conditions that can be recorded and used to generate spatial grammars, while the ability to specify specific material finishes, hardware selection, and overall aesthetic character will rely on the creation of parametrically consistent building elements and “skins”. A direct correlation will need to occur between both the grammatical construct and the modeling of aesthetic refinements. In this way, client will be able to move back and forth between generative spatial preferences and stylistic preferences.

Ultimately, such a tool will need be able to generate geometrically complex plans and massing solutions such that clients have the freedom to radically depart from any notion of a standardized plan. For the sake of simplicity, and in the vein of progressive research, shape grammars have been kept exceedingly straight forward, using orthogonal forms and a regularized planning grid. In the future, as technology makes custom fabrication more normative, it is likely that curvilinear and other complex geometries will be selected for and organized with the framework of a post-industrial design system.

The overriding principle for this methodology is the provision for increased choice and freedom for the consumer relative to the design of homes. Limitations should not be applied that prohibit users from assigning unconventional materials, products or systems in otherwise conventional types of space. Thus, while two separate clients may both specify similar spatial requirements, the appearance of both designs should not, by default be similar. Rather, it is the vision of this research that every design incorporates a range of possible solutions, and never appears to be stranded in a closed system.

As the case study will bein to show, a post-industrial design tool attempts to bring the clients into a more intimate and control oriented relationship with potententil home designs. With the introduction of high quality visualizations, intuitive information navigation structures, and real-time cost feedback, it is imagined that home design can become a radically new and exciting experice for the consumer market.
A CASE STUDY:

To demonstrate the concept, two hypothetical clients have been specified, each representing different concepts of family and habitation. Strategic information about client preferences is obtained through a design parameter interface, which are then interpreted and made manifest into visualizations as a series of design options. Conflicting desires among family members are made known to the clients, and solutions are generated that attempt to meet as many needs as possible. Clients are encouraged to experiment with changing preferences in order to better visualize trade-offs and compromises. In this way, clients go through a process of 'give and take', until a mutually agreed upon design emerges. Additionally, designs are architecturally coerced into being multi-functional, flexible and adaptable. Solutions generated from initial information gathering are then fine tuned using a set of transformation tools that allows the adjustment of individual rooms in terms of material, spatial character, and geometry. Because home use will likely change over time, and because the home will be sold to a different types of families in the future, a series of post-construction variations and adjustments that could occur over the life of the house are provided. As the examples will show, the design is radically different in appearance from a conventional single-family house, yet able to adjust such that any number of eventual users could make use of the space and call it "home". The two profiles are intended to show that changing demographics necessarily lead to new sensibilities in design, and that while the needs of each client are quite different, the house could, given the built-in adjustability, be made to fit other lifestyles.

The two clients reflect demographic characteristics present in today's culture. The clients consist of two individuals who want to co-habit a small house while renting out space to college graduate students. The individuals are not married, and one has a five-year old child. Each client needs space that can provide relatively detached living quarters, while still being integrated into the whole. Both clients agree that an apartment-type space able to accommodate either young graduate students or potentially aging grandmothers is a great idea. This type of program element, the small semi-detached unit, will be an important addition to current housing standards, providing
added versatility and means of generating alternative income. More houses will need to have some form of detached live/work spaces that address issues of privacy, identity, and independence. For instance, it is common for young adults to stay at home during and after college, in which case these students would require a place that is distinctly their own. Privacy from parents, personal workspace, and leisure space, as well as separate bathrooms and kitchens are but a few logical extensions. Similarly, the move from working at a remote office to working at home will have architectural consequences. The case study clients both have a desire to do work from home, however, each has different spatial and aesthetic qualities associated with work.

As the design parameters will show, the clients have different schedules, expectations, habits, and desires. Mapping variables into a spatial grammar will reveal organizations and formal expressions that relate directly to client-initiated decisions. In one instance, this is a dramatic workspace that borders on absurdity; in another, it is a living space that is cleanly proportioned. Possibilities are virtually limitless when a diverse range of individuals has more control of design variables.

Information is collected at the web site via the design interface and stored in a project database. All variables in this initial phase of the design sequence can be adjusted at any point in the process. Thus, if a house exceeds the budget of the client, they can selectively go through their design and make adjustments according to their own priorities. This way, achieving a target budget does not radically impede a client’s values, but forces them to consider what is most important to them.

**Client Profile**

Two professionals. One has a five-year-old son. The clients want to rent out space for 1-2 college graduate students. The clients have no familial relationship, but are happy to share space and resources.
Client 1.1:
Male. Age 38. Occupation: Professional video editor. Wants to commute to work via local subway line. Schedule is often sporadic and unpredictable. He is an outgoing eccentric that loves to challenge the system. His job is just a prelude to a career as a director of underground films that will exist on-line and off. Would not mind having a small studio, or something to do reading and mediation in. Eats out more than he eats in. He is willing to share kitchen and recreation/living space with the other occupants.

Client 1.2:
Female. Age 31. Occupation: Web-graphics designer. Has a five-year-old son. She works almost exclusively from home, and would like to continue doing so. She needs a place to work, sleep, and hang out with her son in the afternoons. She wants to share kitchen and living space with other occupants.

Client 1.3:
Male. Age 5. Kindergarten student. Likes to play just about anywhere. Has occasional temper tantrums, but is generally well mannered.

Client 1.4-5:
Student(s). Age 21-45. In an effort to reduce the monthly mortgage payments, both professionals want to explore the option of subletting space to college grad student(s).
Design interface takes client through a series of information gathering sequences, which then consolidate information in the form of several plan options.

The program checks for parallel and conflicting parameters. When a conflict is detected, the issue is cross-referenced with other data, and a solution is created that demonstrates how adjustments could satisfy both parties. If the program cannot generate a reasonable compromise, then the clients will have to adjust their priorities, and re-compute a solution.

Two 9' average height medium bedroom and one selected by client #2, one for herself and the other for her son. The bedrooms should share a medium sized bathroom and have access to private outdoor space. The bedrooms are designated as closed units that are removed from indoor public space (recreation, cooking, and eating areas). The bedrooms accommodate sleeping, napping, reading, dressing, and listening to music.

One "vertical height" large recreation/living space is designated to have access to public as well as private Two 9' average height medium bedroom and one selected
by client #2, one for herself and the other for her son. The bedrooms should share a medium sized bathroom and have access to private outdoor space. The bedrooms are designated as closed units that are removed from indoor public space (recreation, cooking, and eating areas). The bedrooms accommodate sleeping, napping, reading, dressing, and listening to music.

One vertical height large recreation/living space is designated to have access to public as well as private outdoor space. It should be adjacent to eating and cooking activities, a small bathroom, and the garage. It should be a multifunction space able to accommodate television, listening to music, reading, playing games, and napping.

One average height kitchen/dining area is specified. It should have visual connections to private outdoor space. It should be adjacent to the recreation room and a medium sized garage that holds one car and has room for small workshop. This room is open, not closed.

Client #1 selects one average height large studio. It should include a bathroom, but no kitchen functions. It should be an upstairs unit with a visual connection to the recreation space, and outdoor public as well as private space.

Both clients agree on including an extra large vertical...
height studio. It should have access to both public and private outdoor space, with access to the street. It should also have access to the main recreation space, but is primarily closed. There should be a medium sized bathroom and kitchenette included in the studio and the ability to build a small loft space.

The garage should be an average height medium size, with room for one car and a small workshop. It should have a direct relationship to the street, and be connected to the kitchen and recreation space.

As rooms are added to the design, a cost estimation is provided in the interface, allowing the clients to gauge whether they can afford to make certain decisions. If cost are too high, the client can simply move back and change parameters. For example, changing room heights from "average" to "low", may be cut cost just enough to continue on with the design process.

Having designated the number of rooms, their height, and relationship to other spaces, various configurations are presented that the clients can choose from. Every spatial relationship between spaces has multiple formal possibilities, each of which change the composition of the home. Four primary types of plans tend to emerge based on room arrangement: a longitudinal bar, a compact square, and an "L" shape, and a pinwheel. The client selects one of the four generic plans to work on in the transformation section, where materials, geometric complexity and aesthetic decisions are applied.
Once the number of rooms and sizes have been selected, six plan variation are generated. The clients choose plan "b" for development. At any point in the design process, the clients would be able to return to the initial plan options and explore other possibilities.
Transformations

**Geometric Composition: Symmetry/asymmetry**
The clients want to break up the facade and add some interest to their plan and agree to introduce some asymmetrical translations. This is accomplished by using non-orthogonal rotations and orthogonal translations. By adding some geometric complexity, that is derived from both regulating lines that exist in the local neighborhood, and from the house geometry itself, the form of the house takes on more distinction.

**Walls: Open/closed**
This phase allows the clients to literally open up the house. All wall could potentially be removed, creating a generous "loft" type space. For this study, the clients desire the recreation room to be open the kitchen, but remained closed to the bedrooms. Likewise, bedroom retain their initial configuration for privacy reasons, but the client living upstairs would like to remove some partitions in order to open his space up the rest of the house.

**Material Palatte: Exterior**
The aesthetic character is in dispute. The Client #1 would like a concrete, Ando-like appearance, while client #2 is more interested in a traditional treatment using horizontal larboard siding—more like a prairie style. As a compromise, the lower half of the building is given a wood treatment while the upstairs has a concrete finish. The recreation space is mostly glazing, and uses both wood...
and steel frames.

**Interior Module Definition**
Each client then selects hardware and functional equipment like toilets, cabinets, closet layout, kitchen machines, and bookcases, which are assigned material and aesthetic qualities in the next step. More than one type of style can be chosen for individual rooms, and potentially for every module. Complexity and contradiction can thus be facilitated in the design, where clients may want to have high contrast and eclectic wall treatments.

**Material Palette: Interior**
This section allows the clients to specify specific styles and finishes for their interior module units. Each room is given desired effects from a preloaded palette of styles. The user interface provides a menu of options from which to choose. A search command will allow clients to explore randomly, or deliberately for products that match their needs and desires. Client #1 goes with a concrete finish to compliment the outside. Client #2 likes the Scandinavian look.

**Lighting**
A lighting program will generate four lighting schemes to choose from, that are rendered in a photo-realistic manner. Of course, cost will be displayed for the client to review and aid in the decision making process.
2.4.9
First floor study model showing arrangement of rooms and module units.
Flexibility and Adaptability

Plan Variations:
Student apartment is incorporated into house as family room.
Student apartment becomes "Grandma's" place
Office is turned into another bedroom
Bedroom is turned into formal dining room.

Ground floor is totally opened up as a live work studio with an apartment above and on two the ground floor (garage and original student apt.)
CONCLUSION:

The progression of Western culture, and the technology that defines it, continues to expand the boundaries of personal freedom. With the dawn of industrial culture came a new found faith in tools and machines that has resulted in the break down of social hierarchies that had traditionally kept the majority of people in relatively low levels of power and control. The evolution has been a long and arduous one, and is only now coming of age. The machine not only freed people from disenfranchised trade and manual labor, but also made available products and services never before accessible to middle and lower class citizenry. The availability and affordability of products, due to high volume mechanical production, created a new social structure that was not based on class, but on status. In other words, social status is not exclusively reserved for those born into a class system, but is attained by knowledge gained through higher education systems and a highly technical job market. Mobility has become a way of life. With this ability to move freely with a dynamic economic system, come higher levels of expectation concerning quality of life, which in turn influences the development of new technologies. The effects of this are readily apparent in all aspects of modern existence, whether we are talking about dishwashers in the home, CD players in the car, or cellular phones in our back pocket. All these products emerged as consequences of mass-production and the growing middle class expectation for faster, better and cheaper products able to reduce the drudgery of daily chores and inconvenience.

If the industrial market could be defined by providing better, faster, and cheaper products, then the post-industrial market is defined by providing products that are unique, high quality, and adaptable. Most daily inconveniences have been thoroughly eradicated by automated technologies and smart systems: alarm clocks wake us up, the car shifts gears automatically, and the computer checks our spelling. The demand for something that simply "works", and gets the job done, has been replaced by a demand for products with stylistic appeal and image presence. As a result, rather than disciplines being based on utility and functionality, opportunities abound for the creation of products defined by style, image, lifestyle, and character. The "functionalist" paradigm that early
modern architects keyed into is but a fading shadow in wake of post-industrial culture. Yet, the house, the single largest commodity investment most people ever make, has yet to emerge as an innovative product expressive of the trends and sensibilities of the culture to which is so interconnected.

Throughout the course of the last century, we have witnessed incredible achievements in science, engineering and technology, which have fundamentally changed the way we live, work, and play. The house, on the other hand, has remained a sterile and technologically inept product that pales in comparison to other fields of investigation. Save for a wealthy minority who can afford the services of an architect, the average homeowner seldom has any choice in how their home is to look or function. Unlike contemporary fashion, which moves through styles seasonally, and even daily, the home has retained an allegiance to bygone styles and faux images of pastoral existence. The time has come for a revolution in housing. The post-industrial house is thus a call to arms, a call to action. Freedom, choice, adaptability, and sustainability all represent values that need to be addressed in the future of housing systems. Until such issues are raised and made available to consumers, the home will formally, politically and socially suspended.

The modern-industrial house was an exploration of new materials, the aesthetic consequences of such materials, and the creation of a new style of housing responsive to a changing socioeconomic context. Open architecture became a dominant theme, with strict divisions of space obliterated in favor of ambiguous, free-flowing space.1 Intended to bring the standards of housing up to the standards of a mass-production society, the new style relied on the presence of new technologies and scientific objectivity to generate a theoretical framework for conceiving new homes. Architects attempted to make a

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1 Hitchcock and Johnson. *The International Style.*
link between industrial production and the construction of houses, which resulted in numerous experimental prototypes. That link, while present in some of this century's most interesting houses, was never made successfully outside the realm of architectural discourse. The modern-industrial house never achieved the type of proliferation that mass-produced consumer goods experienced. As a result, they remained one-off solutions that catered less to working class industrial citizens than to eccentric avant-garde aristocrats.

The dream of the factory made house has remained entirely that: a fantasy vision of houses that are mass-produced, inexpensive, and beautifully styled. In actuality, factory-produced homes have come to represent poor taste, cheap construction, and a nomadic trailer park existence. Factory-produced houses have not proved to be significantly better than the conventionally framed house from either a performance or aesthetic standpoint. The tragic fate of the General Panel Corporation, conceived by the great architects Walter Gropius and Konrad Wachsmann, is indicative of a severe disjunction between residential architecture and industrial mass-production. In fact, as rationalized as the Packaged House was, it was ultimately a closed system that was incongruent with many of Gropius' own ideological visions. "(the Packaged House) did not seek to exploit the wide range of industrially produced building materials on the market; it could not, for instance, because of the nature of the panels and the jointing system, readily incorporate standard doors and windows, pre-made roof trusses or ceiling panels then being manufactured by others." In the end, the mass-production methods of building that began with Levittown have continued unabated to this day, were more "open" than the work of some of the best Modern architects. Nonetheless, the housing industry never adopted the concepts of interchangeable components, and has created the homogenous, conservative, and technologically restrained landscapes we have all come to associate with American single-family "sprawl" development.

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2 Herbert. The Dream of the Factory-Made House. Page 254
The expression of industrially produced building products is non-existent in the great majority of developer style suburban homes. While materials, such as steel and engineered wood are common in homes, they are not exploited aesthetically or spatially. Where materials were exploited, as in the Case Study Houses, the influence has been marginal at best. While Wright's Usonian houses were more influential, they never fulfilled the vision of generating entire communities. On this issue, Peter Rowe comments that, "the use of technology as a source of progressive formal and figural expression has languished in the market place. It seems as if the connotations of functional determinism as the expense of familial comfort, coziness, traditions of “hearth” and “home,” as well as a certain cultural continuity with the past, were not ignored."  

We might also add that corporate architecture has largely adopted the type of functional determinism Rowe is speaking about, which stigmatizes the use of industrial materials ever further. Essentially, the associations we have with the office, strip mall, or gasoline station should not be confused with those of the home. The single-family home has become a faux expression of tradition and authenticity that assumes a general desire for homogenous and technically restrictive environments. Changing socioeconomic conditions are in opposition to such a modality: the nuclear family has disintegrated, heterogeneous lifestyles abound, a multivalent culture has emerged, and a radical departure is eminent.  

The architectural discourse concerning the house, which began with the Modernist tradition, has been excluded from the development of the single-family home. This exclusion, a result of complex social, political, and economic forces, has rendered architectural influences mute. This is best represented by the relative anonymity of architects in the public realm, where architects have virtually no market presence, nor do they possess a unified political body able to initiate changes in planning or architectural standards. In

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3 Rowe. *The Shape and Appearance of the American Single Family House.* Page 66

4 Rowe. *Ibid.* Pages 69-70
order for positive change to come about, architectural services need to be made available to consumers as affordable and convenient alternatives to existing modes of design and construction. The architect must look for and take advantage of market trends in order to be a viable player in the emerging electronic economy. The post-industrial market, which is defined by sophisticated computational tools, the interconnectivity of the Internet, and the control of information, is creating an opportunity for architecture to not only re-enter public consciousness, but to also radically change the relationship between homeowners and their house. The relationship is one of control, and if control can be marketed and designed for, then one can reasonably expect new tools and services to surface that put consumers in more control of their environment.

At its core, this thesis is at once a reaction to the unchecked suburban sprawl spreading across the United States, and an affirmation of the Modernist notion that the house is a critical architectural problem. The post-industrial design tool that has been proposed represents an alternative mode of conceiving houses that caters more directly to the homeowner. The tool would vastly improve the experience of buying a new house by providing the consumer with a mechanism for having direct control over the shape and appearance of their home. Additionally, a new residential construction methodology serves to enrich final design outputs with high degrees of adaptability. Having control of multiple variables in the design is perhaps the most important aspect of the tool, and promotes exploration of trade-offs and variations—in effect the freedom to make conscious decisions about. Variable manipulation, combined with a built-in cost estimation device would allow consumers to compare and contrast different solutions in order to arrive at a best-fit scenario. If a house exceeds the budget of a client, then they simply adjust variables according to their own priorities. Thus, if the interior finish is the highest priority for a client, then scaling down the size of individual bedrooms becomes a cost reducing option. Likewise, if a client cannot afford interior finished modules, they could opt to invest all their money in space, and leave the house open for future additions.

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5 Bell. The Coming of Post-Industrial Society. See Pages 14-33
A tool that allows clients in prioritizing the features of a home is not only a more consumer-responsive service, but also a viable model for the mass-customization of other products as well. The computer industry has moved in this direction already. At Dell.com, one can “design” a computer by selecting components that are appropriate from an economic and production standpoint. This way, consumers are not faced with buying a computer chock full of components they may never use. Of course, the computer has far fewer components that a house, but an analogy can still be made between the physical architecture of a computer and the construction methodology I have proposed. A computer is extremely easy to upgrade. The architecture consists of a protective shell, a motherboard equipped with standardized component “slots”, any number and combination of components that connect to the motherboard, and a power supply. To upgrade or downgrade, components are simply swapped in and out, whether they be hard drives, video drivers, sound cards, or external dives such as printers. Extending the analogy to the post-industrial house, houses are custom-specified from the outset, while having the ability to be easily upgraded (or downgraded) in the future. The “shell” remains intact, while interior modular components can be detached, removed, or reseated in a variety of combinations. Like a computer, post-industrial houses can transition from being a high-end performance machines to little more than massive storage containers. As different users appropriate houses, their needs should be reflected in the home. This is quite the reverse from the typical home today, where individuals are forced to adapt to new surroundings, rather than the environment actually adapting to individuals. This paradigm is fundamental to post-industrial economics and product development, and, as this thesis argues, can and should be extended to the home.

Customization of objects ties directly to technological advancement in production techniques and economic stability. The alienation from processes and knowledge used to create the technology that surrounds modern existence is paradoxically liberating. As Rowe writes,

“Technological advancement in the devices we use simultaneously liberates us from a consciousness of the technical effort involved. We can
then focus on the commodities being produced and therefore, on our own preferences in those regards. The result, naturally enough, is a strong tendency toward specific requirements, distinctiveness, and individuality.” ⁶

Assuming the economy continues to stay strong, product customization will grow to include virtually every device we come in contact with, including the average sized house.

The design of homes should not only participate in the technological evolution, but should also expand the role of architecture into the realm of computer science and programming languages. Computer scientists have adopted the word “architecture” as a way of describing the structure of relationships within a program. A critical question naturally arises: can architectural architecture be successfully merged with computational architecture? Bill Mitchell is careful to note the problematics of such a merger, and offers a clue as to how design and computation can be brought together:

“I do not want to suggest that designers follow explicit grammatical rules (though they sometimes do.) Nor do I want to speculate (as an orthodox, cognitive scientist might) that a designer’s mental states are states of an abstract computational device and that design is the mental derivation of shapes. The essential points are that design exploration is rarely indiscriminate trial-and-error but is more usually guided by the designer’s knowledge of how to efficiently put various types of compositions together and that such knowledge can often be made explicit, in a concise and uniform format, by writing down shape rules.” ⁷

The key point here is design knowledge, and that such knowledge resides not in a computational system but in the mind of the designer. Thus, the role of the architect is as

⁶ Rowe, Modernity and Housing. Page 69
⁷ Mitchell. The Logic of Architecture. Page 181
important as that of the software developer. In fact, the program architecture should be subservient to the design intentions of both the architect and client. Because the tool is geared explicitly for clients without any design or construction knowledge, it relies on spatial and structural rules to generate massing models. In terms of style and product selection, decisions are left entirely up to the client and are explicitly not controlled by a computational device. All that the program does relative to style and material selection is connect consumers with products and import objects into the parametric model for the sake of visualization and comparison.

Future development of this project will include a refinement of all the details surrounding a new construction system and a fine tuning of the web interface in order to create enjoyable and attention grabbing experiences. Connecting the tool to manufacturing companies and product catalogues will also be explored to see if the system is a viable alternative. If post-industrial houses can be established as superior products on the market, then they stand a chance of surviving. Of course, if output is low, prefabrication becomes less effective and leads to financial failure. A clear business model will be developed that looks more closely at the relationship between manufacturing facilities, new development, and wide range of material applications.

Thus scope of this thesis has been limited to the design of adaptable detached American dwellings, however, it is important to recognize that all dwellings are part of a larger network of forces that coalesce and create urban and suburban fabrics. The sprawl epidemic defined by asphalt-rich strip malls, auto-oriented communities, and homogeneous curvilinear mazes of identical houses, is a serious land use problem that has yet to be tackled successfully. The deliberate consideration of land use is a critical issue that the post-industrial house will confront. If the post-industrial design tool serves no other purpose than to diversify the formal character of single-family developments, then it will have failed to address other scales of community fabric. A challenge then, for post-industrial housing, will be to enable efficiencies of production, mass-customization, and optimization without annihilating a sense of a cohesive community. Certainly division and distinction are important aspects of any community, and the tool seeks to extend these
qualities, however, they need not be destructive or antithetical to the spirit of a liberal society. In other words, the tool will have to be used in a responsible manner, such that the livability of our cities and neighborhoods is improved, and not simply aestheticized. The way land is zoned, appropriated, and ultimately developed is largely a political issue that is affected by social trajectories and age-old policy. "Along with this sticky question of physical form and social form is the erroneous belief that our community's physical form is the result of free choice, the market's wisdom, and the statistical sum of our collective will. In reality, our patterns of growth are as much a result of public policy and subsidies, outdated regulations, environmental forces, technology and simple inertia as they are a result of the invisible hand of Adam Smith." In other words, changing lifestyles, work habits, and a growing work force of educated and creative individuals cannot change the market without the proper tools to do so. It is not enough to simply assume things will naturally change. But if policy is changed, if people are given access to tools that allow for free choice and decision making, and if new social patterns can be consciously accounted for in such policy and tools, then we may very well see new types of community form.

The house, as a principle means for individuals to engage architecture on a very personal level, has the potential to radically redefine the built environment. Taken seriously, this claim implies a dramatic shift in industry as well as architecture, and represents a movement toward free architecture that is commensurable with contemporary existence. As Lebbeus Woods states, "As this evolution continues in the West, and continues to spread itself into other cultures around the world, more individuals will achieve an unprecedented degree of mobility and choice, with all their existential benefits and burdens." Human freedom, the ability to freely move within social and political space, is at the heart of post-industrial architecture, and by extension, implicates the design and construction of houses and the way individuals choose to live in such constructions.

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8 Calthorpe. The Next American Metropolis. Page 10
9 Woods. Anarchitecture. Page 18
An example of possible architecture reclaimed for the purpose of radical modes of inhabitation.


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